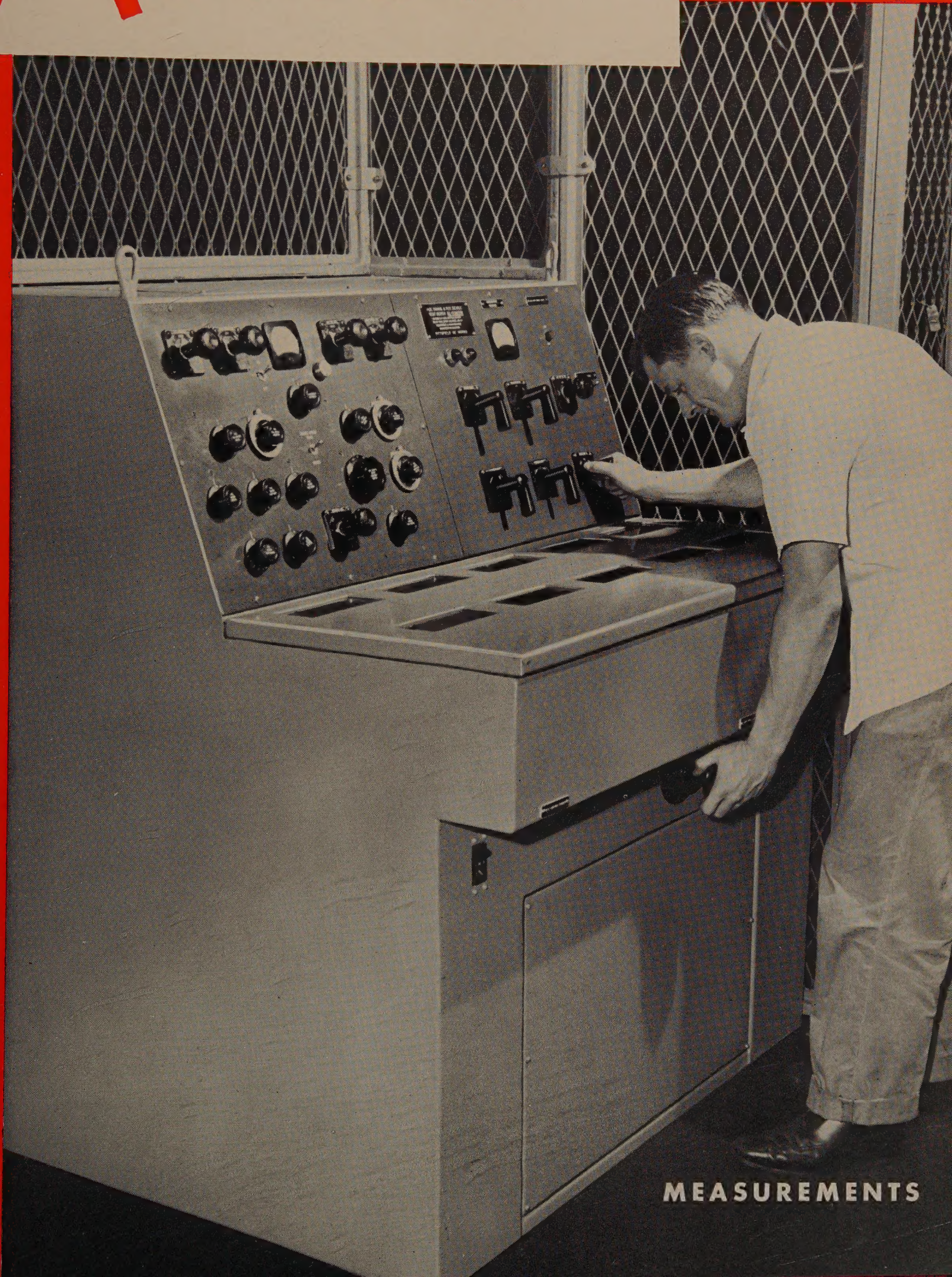
Illinois U Library

GENERAL ELECTRIC
Review

ber

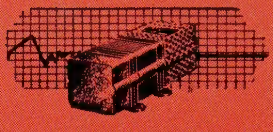
1

NO. 11



MEASUREMENTS

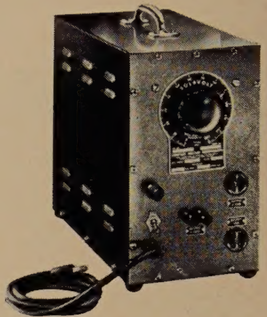
THE SOLA FAMILY OF *5 Voltage Regulator Types* MEETS MOST MILITARY and INDUSTRIAL REQUIREMENTS



SOLA DISCIPLINES VOLTAGE

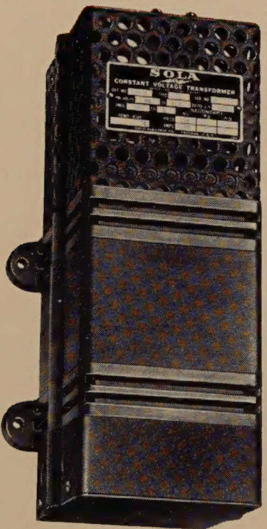
SOLA adjustable, harmonic filtered type CVL:

Regulation ±1%
Harmonic Distortion less than 3
Output adjustable from
0-130 volts



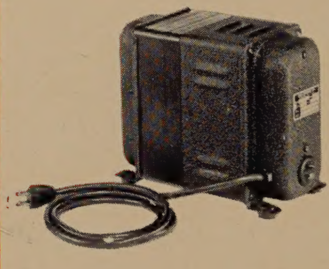
SOLA standard type CV:

Regulation
±1%



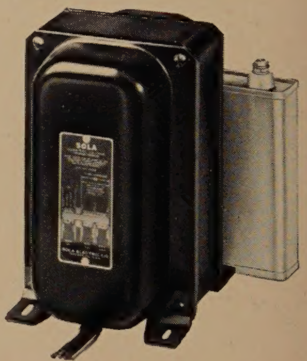
SOLA television receiver type CVA:

Regulation ±3%
Plug-in accessory unit



SOLA plate and filament type CVE:

Regulation ±3%



SOLA harmonic filtered type CVH:

Regulation ±1%
Harmonic Distortion
less than 3%

CHARACTERISTICS OF SOLA CONSTANT VOLTAGE TRANSFORMERS

- Static-magnetic regulation
- Ultra-fast response (1.5 cycles)
- No moving or renewable parts
- No manual adjustments
- Complete automatic, continuous regulation
- Self-protecting against short circuits
- Automatic current limiting action
- Choice of transformation ratios

We invite you to write regarding your voltage regulating problems, or for inclusion of your name on our technical mailing list.

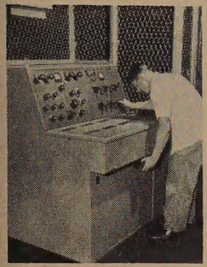
SOLA *Constant Voltage* **TRANSFORMERS**

Made under one or more of the following patents: 2,143,745; 2,212,198; 2,346,621; 2,552,111; 2,489,245 and patents pending.

Transformers for: Constant Voltage • Fluorescent Lighting • Cold Cathode Lighting • Airport Lighting • Series Lighting • Luminous Tube Sign
Oil Burner Ignition • X-Ray • Power • Controls • Signal Systems • etc. • SOLA ELECTRIC CO., 4633 W. 16th Street, Chicago 50, Illinoi
Manufactured under license by: ADVANCE COMPONENTS LTD., Walthamstow, E., England • M. C. B. & VERITABLE ALTER, Courbevoie (Seine), Franc
ENDURANCE ELECTRIC CO., Concord West, N. S. W., Australia • UCOA RADIO S.A., Buenos Aires, Argentina

GENERAL ELECTRIC Review

NOVEMBER, 1951
Vol. 54, No. 11



EVERETT S. LEE
Editor

R. E. MAY
Circulation and
Advertising Manager

J. E. GLICK
Associate Editor

THE COVER

ision instruments applicable to factory tests are cative of the refinements of manufacture found odern industry. The equipment shown here is a ntial transformer test berth in operation on the ory floor. A bridge panel is on the left side, and er controls are at the right. Such installations bine stability, safety, and convenience with racy and general serviceability. (*See p. 14.*) ugh measurement equipments are frequently conspicuous they nevertheless are there in ninence to assure quality products.

ADVERTISING INDEX

ander Hamilton Institute . . . 5
rican Brass Co. . . . 8
pex Electric Corp. . . . 48

ish Thomson-Houston Co., Ltd. . . . 46

bridge Thermionic Corp. . . . 61
adian General Electric Co., Ltd. . . . 61
e & Co., C. P. . . . 2
ostat Manufacturing Co., Inc. . . . 46
nell-Dubilier Electric Corp. . . . 6

en Co. . . . 7
ver-Harris Co. . . . 9

son Swan Electric Co., Ltd. . . . 46

guson Pailin Ltd. . . . 46

eral Electric Co. . . . 55, 59, 62, 4th cover

point Electric Appliance Co., Ltd. . . . 46

Copper Tube & Products, Inc. . . . 61
rsoll-Rand Co. . . . 49

on Specialties, Inc. . . . 58
Manufacturing Co., Inc. . . . 59
ns-Manville Corp. . . . 56

lory & Co., Inc., P. R. . . . 60
ropolitan-Vickers Electrical Co., Ltd. . . . 46
ropolitan-Vickers-GRS Ltd. . . . 46
alex Corp. of America . . . 64

Departure—Div. General Motors Corp. . . . 1
Hermes, Inc. . . . 61
ton Victor Ltd. . . . 46

ite Manufacturing Co. . . . 53

on Can Co., Inc. . . . 59
Industries, Inc. . . . 4
Electric Co. . . . 2d cover
r Carbon Co. . . . 50
gue Electric Co. . . . 3d cover
ens-Arnold, Inc. . . . 51

pil Corp. . . . 54

oreen Instrument Co. . . . 46

EDITORIAL CONTENTS

FRONTISPIECE: New Standard of Length 10
EDITORIAL: Measurements Universal 11

ARTICLES:

Atomic Standard of Length 12
An ultimate primary standard of length—light waves of mercury 198—is now available at National Bureau of Standards
Precision Bridges for Instrument Transformer Testing . . . R. W. Knowles and N. T. Kohlhardt 14
For facility in maintaining high standards of accuracy, safety, and stability in production of instrument transformers
Recent Devopments in Mass Spectrometry . . . Dr. J. G. Hutton and T. E. Usher 18
New knowledge gained from measurements made by mass spectrometry opens new avenues in the chemical and physical world
Miniature Force-and-pressure Cells . . . . H. F. Rondeau 24
Developmental considerations including size, shape, material, surface finish, and lubrication of miniature force cells
New Lighting Measurements Laboratory . Wentworth M. Potter 27
Facilities highly flexible as to room sizes, proportions, reflectance, and type of lighting, and equipment
New Instruments from the Research Laboratory . Dr. C. G. Suits 32
Three useful contributions of research toward improved accuracy and safety in various fields of industrial production
Determining Water Content in Electrical Insulation . . . H. B. Bolson and R. K. Drake 34
A method for determining the moisture content in electrical windings as an aid in future evaluating procedures
Control and Instrumentation Equipment for Large Power Circuit-breaker Testing . . . . A. L. Streater 37
Unusual requirements imposed by high voltages at extremely high interrupting levels are met in these field tests
A Simplified Portable Oscillograph . J. L. Paine and D. M. Ihle 42
New features make possible quick on-the-spot records, as well as the usual records of longer-duration phenomena

DEPARTMENTS: High Lights and Side Lights . . . 17, 36, 45
New Products . . . 47, 48 **Book Reviews** . . 52, 54
Trade Literature . . . 51 **Library Notes** . . 58, 59

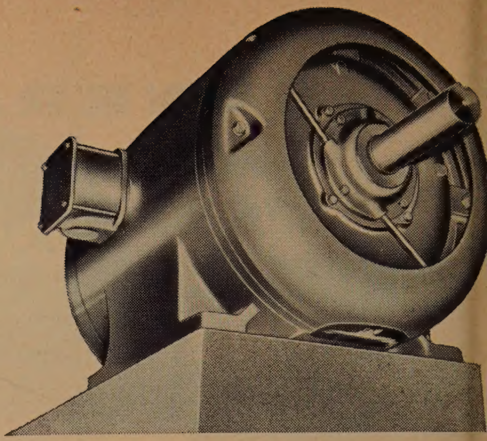
INDEXED: By the Industrial Arts Index; the Engineering Index; and Science Abstracts

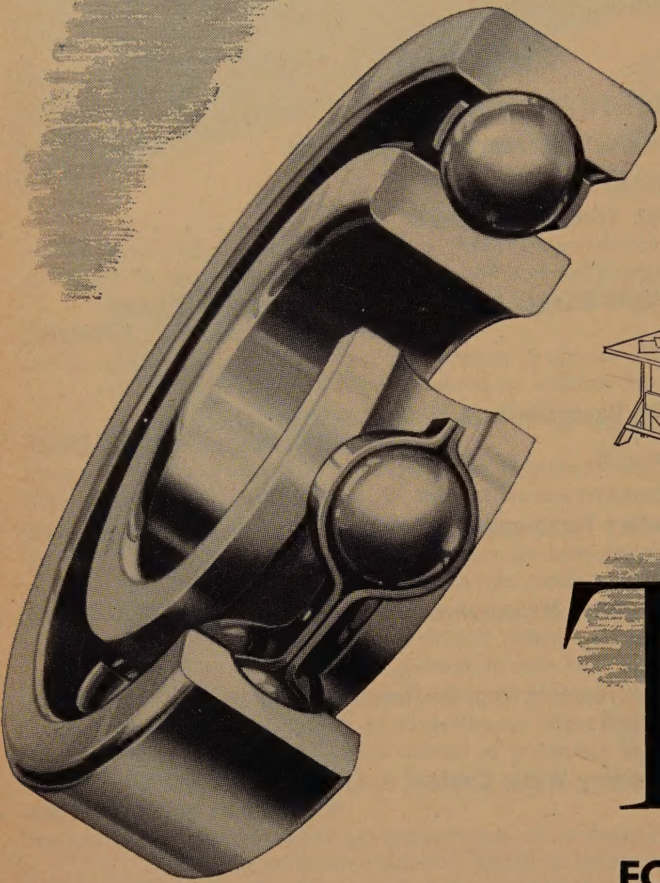
Editorial Advisory Board: **H. A. WINNE, Chairman**
Dr. W. R. G. BAKER • **W. C. BROWN** • **H. V. ERBEN**

ADVERTISEMENTS: The statements and claims presented are those of the advertisers, and their publication does not imply endorsement by the REVIEW.

ADVERTISING DEPARTMENT: General Electric Review, Schenectady 5, New York.
CIRCULATION DEPARTMENT: General Electric Review, Schenectady 5, New York.
SUBSCRIPTION RATES: *Payable in advance.* United States and Possessions, and countries in Pan-American Postal Union, one year $4.00, two years $6.50, three years $8.00. Canada, add $1.00 to above rates. Other foreign countries, add $2.00. Public and college libraries, professors, and enrolled students deduct $1.00 from above rates. SINGLE COPY 40¢.
CHANGE OF ADDRESS: Give old and new addresses. Notices received before the fifteenth of the month will be effective with the next issue.

Entered as second-class matter, March 26, 1912, at the post office at Schenectady, N. Y., under Act of March 3, 1879. Published monthly by General Electric Company, 1 River Road, Schenectady 5, N. Y. Printed in U. S. A. *Copyright 1951 by General Electric Company.*





TEAM

FOR EFFICIENCY AND ECONOMY

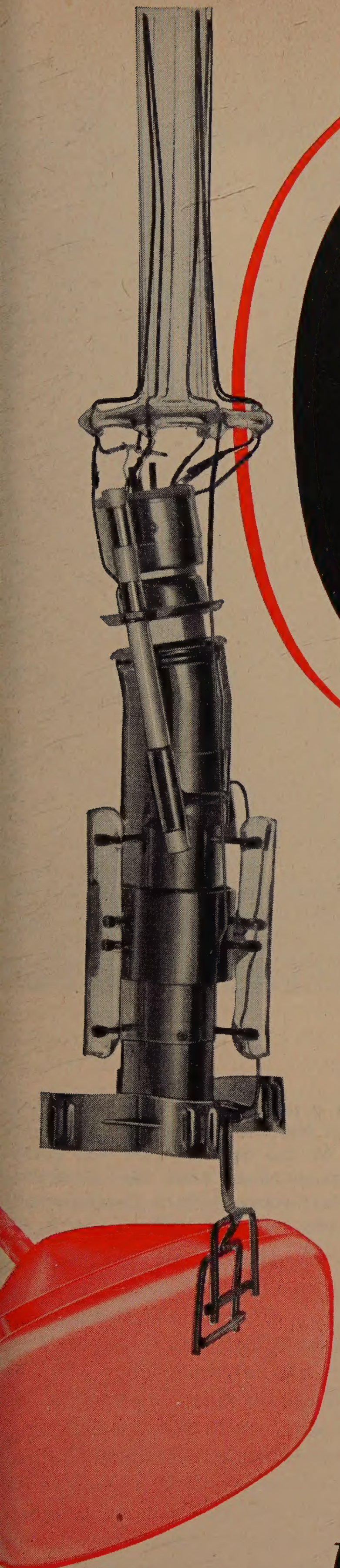
Over the years, SKF engineers have worked closely with engineers and designers in every field of industry. This co-operation, this *team-work,* has helped industry minimize friction in all types of equipment from the smallest motors to the largest blooming mills. Whether you are designing new equipment or looking for efficient, economical replacement bearings, look confidently to SKF for expert, proved advice. Depend on SKF to help you put the right bearing in the right place. 7270-H

SKF
BALL AND ROLLER BEARINGS

8 REASONS WHY SKF IS PREFERRED BY ALL INDUSTRY

integrity • craftsmanship • metallurgy
tolerance control • surface finish
product uniformity • engineering service
field service

SKF INDUSTRIES, INC., PHILADELPHIA 32, PA.—*manufacturers of* SKF *and* HESS-BRIGHT *bearings.*



D-H RADIO ALLOYS

Provide Important Parts for

DUMONT's

Selfocus Teletron

Latest development in picture tubes is the Du Mont Selfocus Teletron which provides *automatic focus at all times without the aid of external circuits or devices.* This eliminates the focusing coil or PM unit now used on standard electromagnetic-focus picture tubes, affording a substantial saving of vital materials in the manufacture of television receivers.

The Selfocus Teletron employs electrostatic focus with magnetic deflection, and this type of receiver is unique among electrostatic-focus tubes because its focusing element is operated at zero volts and is tied internally to the cathode through a resistor.

The elimination of focus circuits from the receiver is made possible largely by the focusing cylinder of the Selfocus picture tube. The unusual design of the cylinder and the precision with which it can be located in the electron gun produce increased picture quality by minimizing defects which have been inherent in conventional picture tubes. With greater control of these defects, it is possible to maintain quality uniformly from tube to tube.

Driver-Harris, who has been supplying Du Mont with alloys for cathode ray tubes for more than 10 years, supplies Stainless Steel 18-12 and special D-H Nickel No. 599 for manufacture into important parts of the electron gun of Du Mont's new Selfocus Teletron. The special requirements of this facet of the television industry are well served by the properties of these metals.

At present, strategic materials and the alloys made from them are inevitably on strict allocation. However, we shall be glad to make recommendations based upon your specific needs, and serve you to the best of our ability.

Makers of the most complete line of
electric heating, resistance and electronic alloys
in the world

Driver-Harris Company

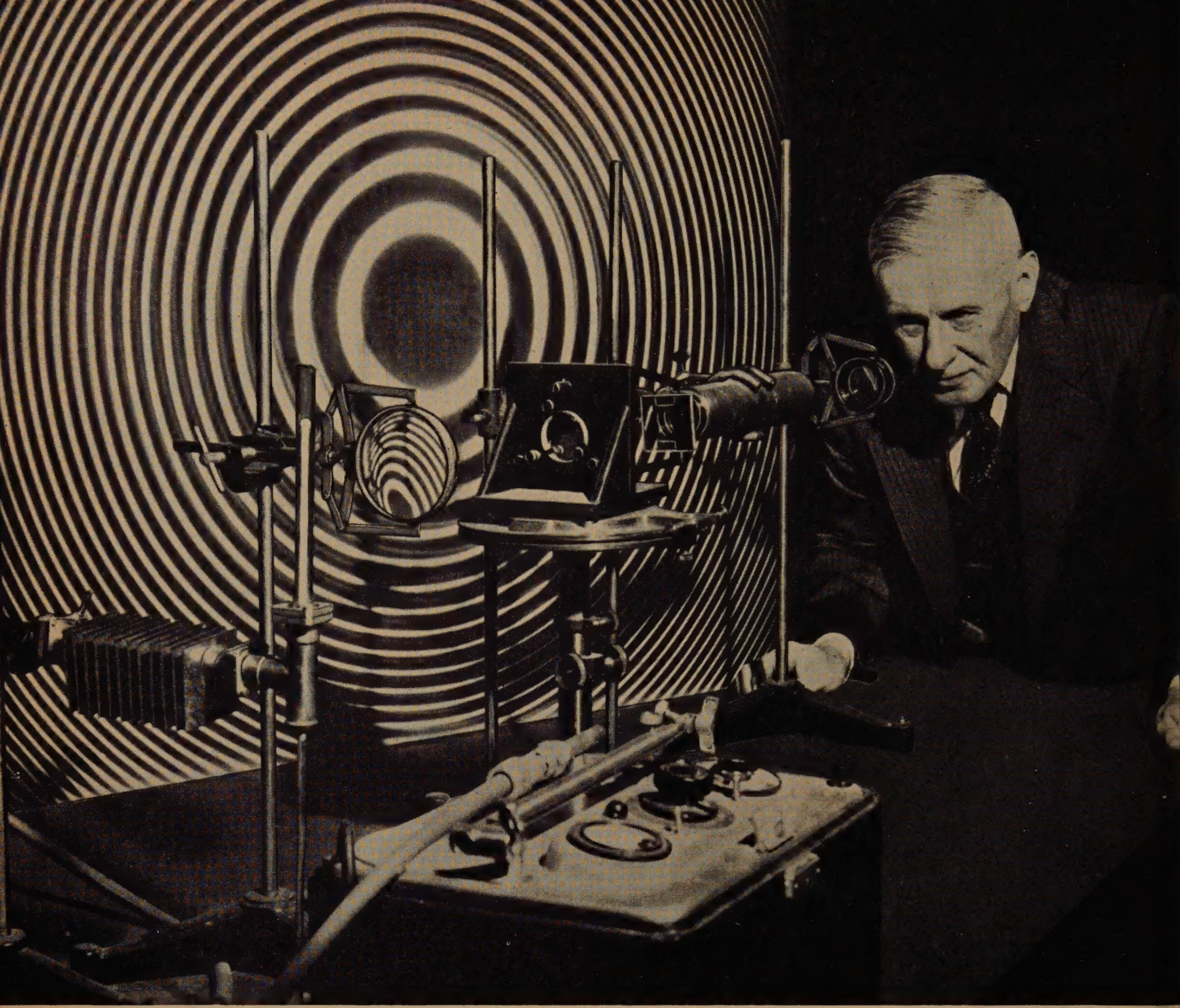
HARRISON, NEW JERSEY

BRANCHES: Chicago, Detroit, Cleveland, Los Angeles, San Francisco

In Canada: The B. GREENING WIRE COMPANY, LTD., Hamilton, Ontario, Canada

SPECIAL PURPOSE ALLOYS SINCE 1899 D/H TRADE MARK REG. U.S. PAT. OFF.

.M. Reg. U.S. Pat. Off.



NEW STANDARD OF LENGTH

Now available as a spectroscopic lamp containing a pure isotope of mercury 198. Dr. William F. Meggers, Chief of the United States National Bureau of Standards Spectroscopy Laboratory, positions the eyepiece of the optical train for observation of the circular interference fringes of green light from the electrodeless lamp. Length measurements based on this interference pattern (background) can be made with an accuracy of one part in one hundred million. (*See p. 12*)

54
11

GENERAL ELECTRIC Review

NOVEMBER
1951

MEASUREMENTS UNIVERSAL

ʼHIS is the eighth Measurements Issue of the GENERAL ELECTRIC REVIEW in as many years. ısurements never cease. They continue with the ancement of knowledge. As Lord Kelvin said:

> "When you can measure what you are speaking about and can express it in numbers, you know something about it."

he years have brought outstanding contributions ı the engineers and scientists who have given of r lives to measurements and measuring instruments. y have made them to be of universal application. f outstanding recent interest is a series of most sual measurements being reported in *SCIENCE* J. R. Arnold and W. F. Libby, of the Institute of clear Studies, University of Chicago. They are us- the radioactivity of carbon to measure age. The ıes obtained are based on 5568 ±30 years as the -life of radiocarbon. Several samples of wood were ıd to be older than 20,000 years. Some scrolls from estine of the Book of Isaiah gave an age measure- ıt of 1917 ±200 years. These scrolls were thought be first or second century B.C. Several hundred er samples have been measured with most interest- results. Thus from the nuclear work of the past years has come a new measurement means for king back into history with remarkable exactness.

'he Sixth National Instrument Conference and ıibit, held this past September in Houston, Texas, e opportunity for visualizing the scope and extent ıew measuring instruments for industry. Here was ıered a wealth of products representing the world's st industrial instruments. As they have been in- luced and used, they have provided for the world's ıtest industrial output.

'he Conference and Exhibit was under the sponsor- of the Instrument Society of America, meeting tly with twelve other groups from the engineering scientific societies of our land, with an outstanding gram of meetings describing the latest advances in ısurements in their respective fields. To see these ruments of every variety and to appreciate their ic performance is to visualize the complete extent of ineering and scientific measurement interest which hes into every industrial avenue for the betterment ıankind.

ı 1954 the Conference and Exhibit will be held in ladelphia and will be international in scope. It is significant that measurements which are universal will be represented in an exhibit and conference that is international. It will be held in this country where from our present position our world responsibility is ever widening.

World understanding through scientific discoveries, engineering achievements, and measurements has forever been prominent. In the Spring of 1939 I was privileged to speak with the Astronomer Royal in London. He told me of the magnetic explorations of the seas in a ship under international sponsorship which, at that moment, was threatened by the gathering war clouds. Soon afterward, I was speaking with the scientists in the Reichsanstalt in Berlin, and they regretted that the then scheduled international agreement, wherein the electrical standards of the nations of the world would be expressed in terms of Length and Mass and Time, would have to be postponed.

Such was then necessary. But with the close of the war, the work was resumed and carried to a successful conclusion so that beginning with January 1, 1948, the electrical industry discarded the mercury ohm and the silver voltameter, and replaced them with length from light, with mass from the attraction of the earth, and with time from the movement of the stars. This was an outstanding contribution by the National Standardizing Laboratories of the great nations of the world and was the culmination of over forty years of the finest of measurements and measuring technique. And in this the scientists and engineers of our own United States National Bureau of Standards were leaders. We can be proud of their accomplishments.

This year our National Bureau of Standards celebrates its fiftieth year. These have been fifty years of contribution to many outstanding advances. We salute the Bureau, and express our faith that the years to come will be equally productive—yes, even greater. We are glad to reprint in this issue of the REVIEW an insight into their work in advancing standards of measurement so necessary to man in his everyday life.

And we are glad to recognize the engineers and scientists in General Electric Company who see in measurements the continuing opportunity for making available new knowledge to give certainty to product design and manufacture. This is the role of measurements in industry. Of their fundamental need there is no end.

EVERETT S. LEE

ATOMIC STANDARD OF LENGTH

An ultimate primary standard of length—light waves of mercury 198—is now available in a lamp developed by the National Bureau of Standards

In recognition of the National Bureau of Standards' Fiftieth Anniversary, we are reprinting with their permission this article on measurements, from the NBS Technical News Bulletin *of March, 1951.*—Editor

THE availability to science and industry of an ultimate standard of length was announced recently by the National Bureau of Standards and the Atomic Energy Commission. The standards consist of spectroscopic lamps containing a single pure isotope of mercury. These lamps enable any research organization that has the auxiliary optical equipment to have for the first time an ultimate primary standard of length in its own laboratories.

Distribution of the lamps will be handled by the National Bureau of Standards. They will be available to qualified government, industrial, and educational laboratories, both in this country and abroad, engaged in precision length measurements and related research.

The NBS-Meggers Mercury 198 Lamps,(1) prepared under the direction of Dr. W. F. Meggers, Chief of the National Bureau of Standards Spectroscopy Laboratory, contain about 1 milligram of mercury of atomic weight 198. Mercury 198 is obtained by the transmutation of gold in a nuclear chain-reacting pile. In 1931, Dr. Meggers suggested that an ultimate standard of length could be obtained if one of the even atomic-weight isotopes of mercury could be isolated from the seven that occur mixed together in natural mercury. At that time no means existed for obtaining useful amounts of a single isotope. In 1945, following the war-time development of the nuclear pile, the production of a useful quantity of artificial mercury 198 was achieved at Oak Ridge by subjecting pure gold to intense neutron bombardment.

Mercury 198 is sealed in a small glass tube and caused to glow brightly by the application of high-frequency radio waves. The light waves emitted by the single isotope have extremely sharply defined wavelengths that can be used for length measurements of great precision. These particular waves are uniquely characteristic of the mercury and remain unalte with time.

The new standard of length is based upon the wa length of the green light emitted by the lamp. T wavelength, near 21 millionths of an inch, is cons ently emitted with a reproducibility greater than part in a billion. Length measurements based upon can readily be made with an accuracy of one part 100 million. New apparatus now under construct at this Bureau is expected to extend the accuracy one part in a billion.

The measurement of length in terms of a charact istic radiation from a particular atom involves optical technique of interferometry whereby the se ration of two precisely flat plates is measured in te of the number of wavelengths of light contained in distance between them. Because the number of wa contained in any practical distance is determina without error and because the wavelength of the li from a single, pure isotope of even atomic weight is sharply defined, accuracies of measurement heretof impossible can be obtained.

Although the world's official primary standard length is still the distance between two lines on a me bar, practically all precise measurements of length the twentieth century have been made and will conti to be made with light waves. When accuracy grea than the part in 10 million possible with the stand meter is necessary, only the new spectroscopic stand meets the need.

Up to the present time the wavelength of the red li from cadmium has been used as a wavelength standa In 1927 the International Conference of Weights Measures provisionally adopted the value 1,553,163 wavelengths of cadmium red radiation as equal t meter. In 1948 the NBS proposed that the meter defined in terms of the radiation from mercury 1 This is now under consideration. Present measu ments show that 1,831,249.21 wavelengths of the gr radiation from mercury 198 equals 1 meter.

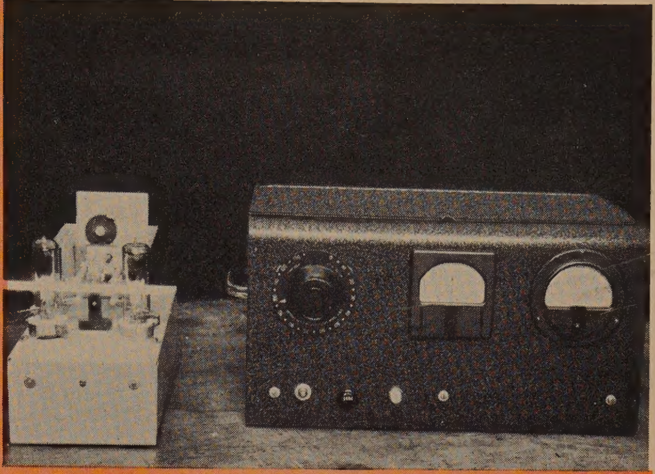
The fundamental advantage of mercury over c mium is that the wavelengths of the light from merc

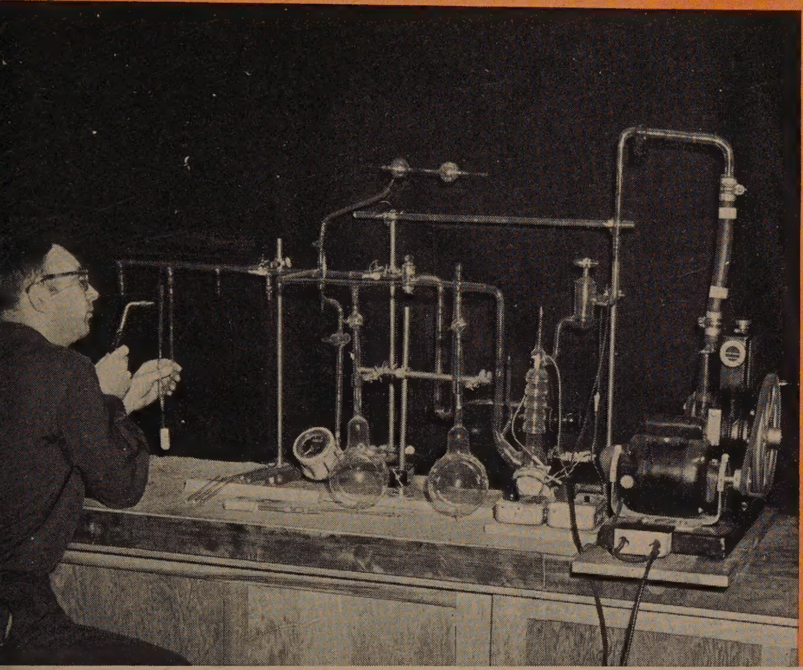
---

(1)References are listed at the end of the article.

All requests for information and applications should be addressed to the Co-ordinator of Atomic Energy Commission Projects at the National Bureau of Standards, Washington 25, D. C.

This lamp, after continuous excitation for over 10,000 hours in a life test at the NBS, showed no significant deterioration





Sealing off a mercury 198 lamp after it has been evacuated and a measured amount of argon and pure Hg 198 admitted

much more sharply defined. Cadmium consists of
principal isotopes, which are not separated. They
t light of slightly different wavelengths. When
gth measurements are made with light having this
ture of wavelengths, a region of confusion results
t limits the accuracy. Mercury has other advan-
es: (1) the atoms are heavier, move about more
ly, and hence disturb the wavelength less; and (2)
light can be obtained without heating the mercury
high temperature and thereby speeding up the
nic motion. When all the advantages are consid-
, it is found that the mercury 198 provides a stand-
300 percent more accurate than cadmium. The
of the NBS-Meggers 198 Lamps appears to be in-
e; a lamp under continuous excitation over a
od of more than 10,000 hours showed no significant
rioration.

Recently the Oak Ridge Laboratories of the Atomic Energy Commission have succeeded in isolating practical quantities of mercury 202 by magnetic separation methods. The advantages of this isotope over the 198 isotope are negligible except for certain important problems in atomic research. Mercury 202 lamps, if needed for research in atomic physics, can also be obtained from the National Bureau of Standards by special arrangement. The wavelength of the light from the 202 isotope has not as yet been accurately measured, and hence the information needed for its use as an atomic length standard is not available.

References

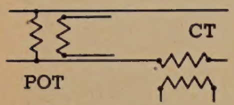
"Light Wave of Mercury 198 as Ultimate Standard of Length," NBS *Technical News Bulletin*, vol. 31, Dec. 1947, p. 133.

"Lamps and Wavelengths of Mercury 198," by W. F. Meggers and F. O. Westfall, *Jour. of Research* NBS, vol. 44, May 1950, p. 447. Research Paper 2091.

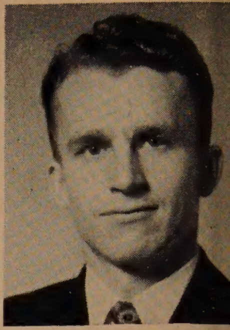
PRECISION BRIDGES FOR INSTRUMENT TRANSFORMER TESTIN

For facility in determining and maintaining the high standards of accuracy, safety, and stability required in production of instrument transformers

By R. W. KNOWLES and N. T. KOHLHARDT
Transformer and Allied Products Laboratory
General Electric Company



Robert W. Knowles



Norman T. Kohlhard

AS A measure of final product quality, there are few tests equal in importance to those which determine the true ratio and phase angle of current and potential transformers. Instrument transformers are essential parts of many electrical measuring and control systems in that they provide a means of isolating equipment and personnel from high voltage-high current circuits; but to be a completely useful part of these measuring circuits, instrument transformers must change the magnitude of high primary voltages or currents to low secondary values that have an exact ratio and phase relationship to those in the primary. Thus, the transformation characteristics of the transformer must be known to a high degree of accuracy.

The American Standards Association has outlined exact standards of accuracy to be met by instrument transformers for various conditions of secondary load.(1) Careful measurements with precision equipment assure that transformers meet these standards. The allowable testing tolerance for instrument transformer certification is ±0.1 percent for ratio and ±3 minutes for phase angle. Therefore, the measuring equipment used for testing should be capable of detecting ±0.01 percent in ratio and less than 1 minute of phase angle.

Where a large number of instrument transformers covering a wide range of ratings must be tested on a production basis, the measuring equipment must not only have high accuracy, but must be sturdy, serviceable, safe, and easy to operate. The equipments to be described are designed to minimize testing time by providing simplicity of operation without sacrifice of accuracy.

General Description of Equipment

The installation of equipments for current and potential transformer testing are shown respectively in FIG. 1 and in the COVER illustration. Permanently placed test berths house the measuring bridges and test-power controls. Transformers for test are placed in adjacent interlocked areas. With the measuring bridges and all metering and power controls housed in a single cabinet, and all high-voltage components located within the interlocked area, safety and convenience is obtained with a minimum of floor space.

While the theory of many circuits for instrume transformer testing may be found in numerous texts the circuits that have been chosen for the equipm described in this article lend themselves to the ap cation of null-balance bridge principles. In each circu the design is such that direct readings may be obtai for both ratio and phase angle, thus eliminating need for any lengthy calculations. Particular attent has been paid to the selection of bridge-network co ponents so that stability can be maintained in fact service.

Current Transformer Test Equipment

Measuring Circuit

The current transformer test circuit is shown in F 2. A standard transformer of known ratio and ph angle is connected in series with the transformer un test so that the secondary currents I_S and I_X, flow in the resistance R_e oppose each other. The differe current produces a resultant voltage drop which rep sents the deviation in ratio and phase angle betw the transformer under test and the standard refere transformer. The two components of the differe voltage are then balanced against voltages obtai from the bridge network potentiometers R_M and until a null point is reached as indicated by the tector D. The voltage components supplied from bridge potentiometers are proportional to the stand current I_S, the voltage drop across R_M being in ph with I_S and the voltage across R_ϕ in quadrature w I_S. With this particular circuit it is possible to meas extremely small deviations, the sensitivity of the tector being the only limiting factor.

This general type of circuit was originally descri by A.M.H. Arnold.(3) In Arnold's circuit, the brid network voltages were obtained from a low-resista slidewire and a variable mutual inductor. The l resistance slidewire and mutual inductor are delic components that present problems of maintenance a calibration for application in a factory environme Therefore, these components have been replaced b sturdier bridge network.

The mutual inductor is replaced by a phase-s network of resistors and capacitors R and C adjus the test frequency, so that a quadrature voltage is eloped across the high-resistance potentiometer consisting of three dials marked directly in minutes. e low-resistance slidewire is replaced by a three-l high-resistance potentiometer R_M marked directly atio correction factor. This system has proved to be ellent for factory application, and has required le maintenance.

---

(1)Numbered references are listed at the end of the article.

dge Network Design

he bridge network is so designed that the in-phase nponent of the difference voltage is proportional to (1-R_M), where (1-R_M) is the ratio correction factor ding subtracted from unity. The quadrature com-ent of the difference voltage is proportional to I_S an 1′), where ϕ is the dial marking of R_ϕ in terms of utes. At balance, the expression for the true ondary current of the unknown transformer with pect to secondary current of the standard trans-ner S is:

$$_X = I_S + I_S(1-R_M) + jI_S(\phi)(0.00029) \quad (1)$$

rom which:

$$\phi_1 = \tan^{-1}\frac{(\phi)(0.00029)}{(2-R_M)} \quad (2)$$

here $\phi_1 =$ the phase angle between I_X and I_S

quation (2) reveals that, for angles less than 50 utes and for ratio differences less than 1 percent, bridge dial reading ϕ will be equal to ϕ_1. In most es, current transformers are well below 50 minutes ngle and deviate less than 1 percent from nominal o so that the application of corrections to the phase le dial reading is seldom required.

n terms of the nominal and true secondary currents he transformer being tested, ratio correction factor be expressed as:

$$\text{RCF} = \frac{k_T}{k_T'} = \frac{I_X'}{I_X}$$

here k_T=true ratio; I_X=true secondary current; $_T$=nominal ratio; I_X'=nominal secondary current.

or the test setup, a standard transformer ratio is ys chosen that is the same as the nominal ratio of transformer under test so that $I_S = I_X'$. Therefore

$$\text{RCF} = \frac{I_S}{I_X} \quad (3)$$

substituting I_X from Equation (1) into Equation

$$\text{RCF} = \frac{1}{\sqrt{(2-R_M)^2 + [(\phi)(0.00029)]^2}} \quad (4)$$

or angles of less than 50 minutes Equation (4) mes:

$$\text{RCF} = \frac{1}{(2-R_M)} \quad (5)$$

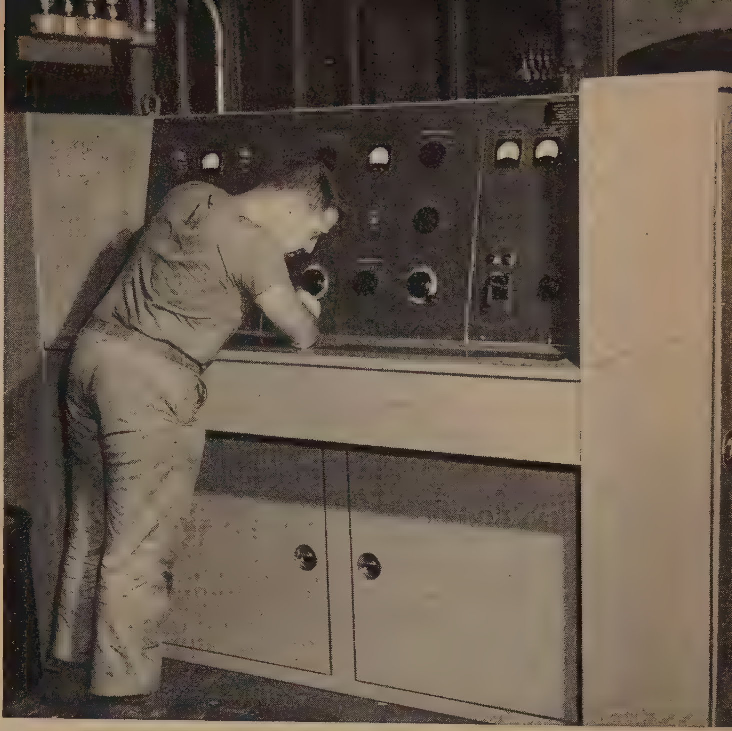


Fig. 1. Current transformer test berth in operation on the factory floor. The bridge occupies the center panel, with power and meter controls on the right and left panels

Equation (5) indicates that when the dial setting of R_M is in the region of 1.01 to 0.99 (ratio deviation of 1 percent or less), the dial readings are in terms of ratio correction factor.

The bridge is direct reading, provided that corrections for ratio and phase angle of the standard transformer are negligible. It is possible to obtain standards that are not off ratio by more than 0.05 percent and have a phase angle of ±1 minute. Corrections for the standard may be applied to the readings when necessary.

The range of transformers that may be tested is governed by the standard transformer ratios available. In practice, precision multiratio standards are used that permit testing ratios ranging from 5:5 to

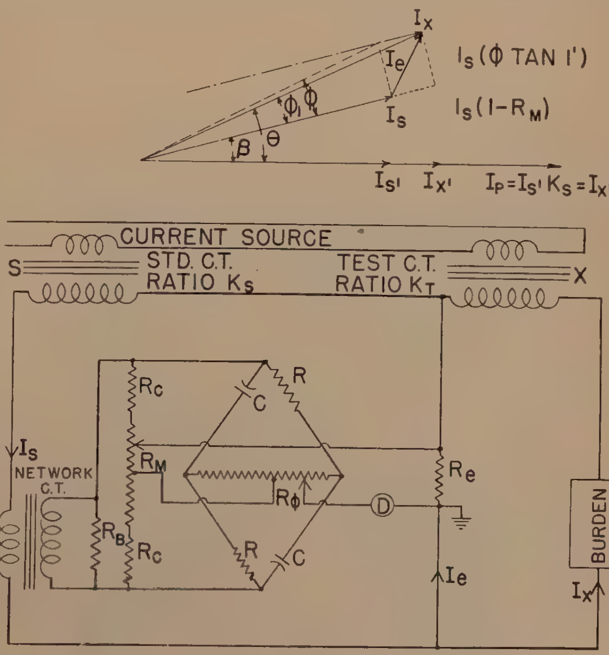


Fig. 2. Current transformer test circuit

6000:5. The ratio dials of the bridge cover a range of 1.2 to 0.8 with steps of 0.0001 available on the last dial, while the phase-angle dials cover a range of ±400 minutes with steps of 0.2 minute on the last dial.

An electronic frequency-selective amplifier with a sensitivity of three microvolts is used as a null detector. The amplifier employs tuned twin-T feedback networks to obtain suppression of unwanted harmonics.(4),(5)

A dependable accuracy of ±0.05 per cent in ratio and ±1 minute in phase angle may be obtained in the bridge network. The standard transformers are calibrated by absolute methods to a tolerance of ±0.05 percent in ratio and ±1 minute in phase angle, so the over-all accuracy of the current transformer equipment is within ±0.1 per cent and ±3 minutes.

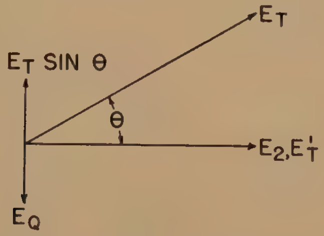
Potential Transformer Test Equipment

Measuring Circuit

The schematic diagram of the measuring circuit for testing instrument potential transformers is shown in Fig. 3. The transformer under test is compared to a standard transformer of known ratio and phase angle, with the low-voltage output E_S of the standard applied to a resistance divider R_1 and R_2 that allows for adjusting the magnitude of the voltage E_2. The low voltage E_T of the transformer under test is adjusted for phase angle by the phase control so that the voltage E'_T is in phase with the voltage E_2. A point of balance is reached when E'_T and E_2 are equal in magnitude and in phase, indicated by a null reading on the detector.

For this type of network, the general balance equation for the voltages involved is:

$$E'_T=E_2=\frac{E_S R_2}{R_1+R_2} \qquad (6)$$



For phase angles of less than 50 minutes, E_T is eq in magnitude to E'_T within 0.01 percent, so that Eq tion (6) may be stated in terms of the transformer rati

$$k_T=\frac{R_1+R_2}{R_2}\times k_S$$

where: k_T = ratio of the transformer under test
k_S = ratio of the standard transformer

Measurement of Ratio

For ratio measurements it is desirable that the va able arm of the resistance divider R_1 read directly ratio correction factor. To accomplish this, the divi resistor values and the standard transformer ratio chosen to satisfy Equation (7) in terms of nomi ratios. Thus, if the true ratio of the transformer un test is equal to the nominal value, there is no need fo change in the resistance of R_1. For all initial setups, is marked for an RCF of 1.0000. When the ratio de ates from the nominal value, R_1 is changed from initial value until a balance is reached, and the bri network indicates the true ratio of the transforn under test, as given in Equation (7).

The potentiometer R_1 is made up of four deca resistance units so that a range in RCF of 0.9 to 1. covered with minimum steps of 0.0001. It is necess to choose a ratio for the standard transformer that constant fraction of the nominal ratio to be checke

The accuracy of ratio measurements depends for most part on the accuracy to which the ratio of standard transformer is known. By absolute calibrat methods, the ratio of the standard may be measured within ±0.05 percent. In the resistance divider, ratio of the resistances R_1 to R_2 may be held to a tol ance of ±0.02 percent; and, considering these circ elements, ratio measurements may be made to accuracy of ±0.1 percent.

Measurement of Phase Angle

The phase angle control supplies a quadrature vo age E_q which may be adjusted in magnitude by potentiometer R_p to cancel the quadrature compon of the test transformer voltage, E_T sin θ. The angl

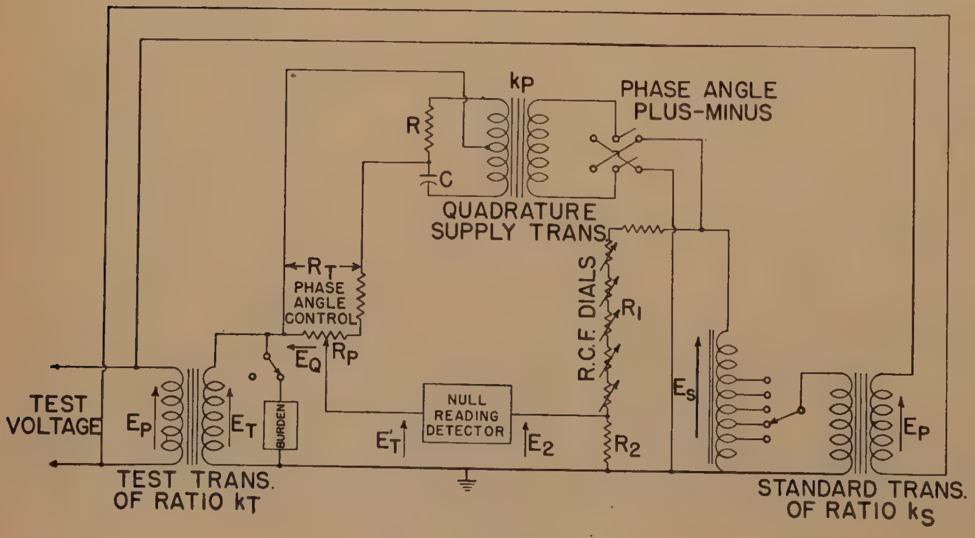


Fig. 3. Potential transformer test circuit

e phase angle between E_2 and E_T, so that, knowing hase angle of the standard transformer, the phase e of the transformer under test may be determined measure of θ. The phase-angle potentiometer R_p librated in terms of sin θ and marked in terms of ites.

balance, the equation for the voltages involved is:

$$E_q = E_T \sin\theta \qquad (8)$$

ne voltage E_q is placed in quadrature with the ige E_2 at the test frequency by adjustment of the parameters R, C, and R_T on the secondary of the ed supply transformer. Since the voltage E_q is ortional to the low voltage E_S of the standard sformer, it is also proportional to the nominal ratio ne transformer under test. The voltage component in θ is proportional to the true transformer ratio, at the phase-angle dial readings are in error by the ' of the transformer being tested. This is not serious, ever, since this error is usually less than 0.5 percent, corrections may be applied when the deviation in is large. The circuit elements in the phase-angle rol may be adjusted to an accuracy of ±0.5 percent e dial reading, and the angle of the standard trans- er may be determined to ±1 minute so that the racy of phase angle readings is better than ±3 ites.

ne phase-angle potentiometer R_p has been designed over angles of plus or minus 0 to 100 minutes in ranges, so that readings of 0.5 minute may be ined on the lowest range. For phase angles in egion of ±100 minutes, the ratio reading may be ted to the extent of ±0.4 percent so that a cor- on for large angles may be applied to the ratio ings.

ne range of potential transformer ratios that can be red is determined by the range of ratios available he standard transformers. In practice, multiratio lards have been used in conjunction with a tapped transformer which extends the range of ratios that can be handled. As many as 24 different ratios can be tested by use of three high-voltage standards and an autotransformer. Voltages that have been covered range from 150 volts to 269 kilovolts.

The detector requirements for the potential transformer bridge are not so stringent with regard to sensitivity as is the case with the current transformer bridge, a sensitivity of 10 to 12 millivolts being adequate. An electronic frequency-selective amplifier incorporating harmonic suppression has been used as a detector.$^{(4),(5)}$

Summary

As equipments for production instrument transformer testing, the bridges described are particularly suitable because:

(1). Accuracy of ±0.1 percent for ratio and ±3 minutes for phase angle permits certification of transformers in the highest-accuracy class

(2). Direct readings of ratio correction factor and phase angle over the range of 0.99 to 1.01 and ±50 minutes eliminate the need for calculations

(3). Safety is obtained by use of comparison-type circuits which isolate the measuring bridges from high testing voltages

(4). Stability, obtained through the use of high-resistance network components, avoids the need for frequent calibration and servicing.

References

(1)*American Standards for Transformers, Regulators, and Reactors*, Section C57.13. Approved by the American Standards Association.

(2)B. Hague: *Instrument Transformers*, London, Sir Isaac Pitman and Sons, Ltd., 1936. This text has an extensive bibliography on the subject.

(3)"Current Transformer Testing," by A. M. H. Arnold, *Journal I.E.E.* vol. 74, (1934), pp. 424-437.

(4)"A New Type of Selective Circuit and Some Applications," by H. H. Scott, *Proc. IRE.* February, 1938.

(5)"Impedance Network for Production Testing Current-limiting Reactors," by S. C. Leonard, GENERAL ELECTRIC REVIEW, vol. 50, October, 1947, p. 31. Null Detector.

IGHTS AND SIDE LIGHTS

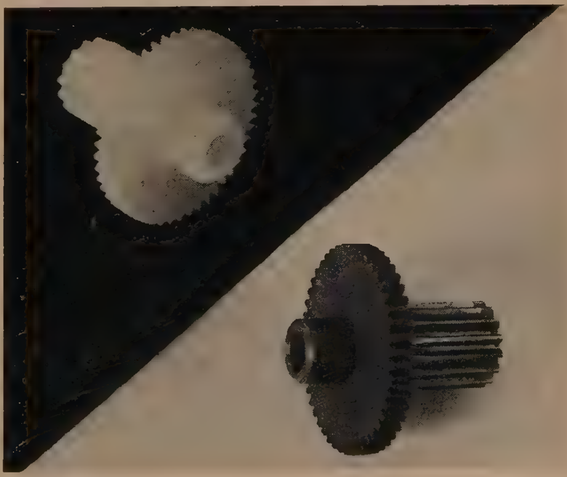
on Gears for Oscillating Fans

st savings averaging 63 percent have obtained on gears for the oscillating y replacing three metal gears with ed nylon gears.

tating at a speed of 32 rpm with a num torque of 6.75 oz-in., a molded worm wheel and pinion alone per- ost savings of 65 percent, as com- with the original construction of a pinion and laminated plastics gear hobbing, cutting, and assembly tions were required.

ause an injection press specially ned for economical nylon molding d, no machining operations are re- d on the wheel and pinion. Assembly tions are also eliminated, since the arts are molded as a unit.

ts show that the nylon gears now used in two of the oscillating fans have excellent wear characteristics as compared with the previously used steel and laminated gear. Quieter operation, in addition to substantial cost savings, has also been obtained.

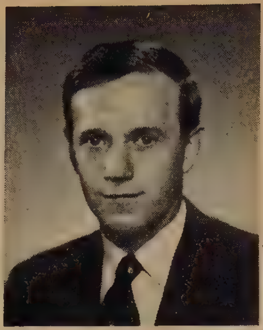


Nylon gears are replacing combination metal and laminated plastics gears in oscillating fans, with substantial cost savings

RECENT DEVELOPMENTS IN MASS SPECTROMETR

New knowledge gained from measurements made by mass spectrometry opens to science new avenues in the chemical and physical world

By Dr. J. G. HUTTON and T. E. USHER
General Engineering Laboratory
General Electric Company



John G. Hutton

Thomas E. Ush

WHILE history has it that Benjamin Franklin speculated in 1750 that electricity was caused by the flow of a large number of discrete charges rather than a continuous process, it was not until 1833 that the first experimental evidence of this hypothesis was offered. At that time Faraday, through his studies in electrolysis, inconclusive though his results were, presented strong evidence in favor of the atomic nature of electricity. During the next 70 years various researches in the phenomenon of the glow discharge and studies on vacuum led to the acceptance of the term "electrons" for cathode rays and to the conclusion that these were negatively charged.(1)

In order to determine whether these particles were all alike, Sir J. J. Thomson performed his classic researches to measure the velocity of the electron and its mass-to-charge ratio. In his apparatus, an evacuated tube, electrons were obtained by cathode discharge and collimated by means of disks with small circular apertures. The path of the electrons was indicated by means of a fluorescent screen suitably placed in the end of the tube. Mounted on the neck of the tube, and external to it, were two solenoids; current through the coils set up a horizontal magnetic field whose lines of force were perpendicular to the electron beam. Two conducting plates were mounted horizontally within the tube and in the same area as the solenoids; high voltage applied to the plates provided a vertical electric field crossing the magnetic field. The diameter of the solenoids was equal to the length of the deflecting plate, and the fields thus occupied the same region. The directions of the fields were such that one deflected the electron beam vertically upward when acting alone, while the other, alone, deflected it vertically downward. The strengths of the fields were adjusted so that when acting together, the net deflection of the electrons was zero. Under such conditions the forces on the electron due to the two fields were equal and opposite. By measuring the deflection of the electron beam due to the magnetic field alone, and also equating the forces on the particle due to each field, the mass-to-charge ratio could be determined.

Meanwhile another discharge phenomenon had been observed, and studies led to the establishment of
positive rays. Wien, using similar techniques to Th
son's in his work on electrons, determined the mass
charge ratio of positive rays. Thomson expanded
work with apparatus similar to his apparatus for e
trons except that he replaced the fluorescent sc
with photographic plates. By measurement of
masses of positive rays he showed that they resu
from ionization of gas molecules; they were posi
ions.

His apparatus was, indeed, the first mass spec
graph. Designed for the accurate determinatio
isotopic mass, it was followed later by its compan
instrument—the mass spectrometer—by means
which, originally, the relative abundance of isoto
was determined. In what follows, since the emph
will be on the mass spectrometer, that term will be u
throughout.

MASS SPECTROMETERS

The unique property of the mass spectrometer,
it is sensitive to the mass of the element or compo
introduced in the gaseous form in its ion cham
presented to scientists a means for opening up
avenues in the chemical and physical world. By
application of this powerful tool, the discovery of
isotopes, and the correct isotope ratios within elem
known to have such isotopes, was made possible.
names of Aston in England, and Dempster, Mattau
Urey, and Nier in this country became synonym
with the mass spectrometer and the physics
chemistry of isotopes.

Meanwhile, in many countries of the world m
thought, study, and experiment was being given to
possibility of releasing the energy that was known t
stored within the atom. In fact the explosion of
atom bomb at Alamogordo, New Mexico, in
marked the end of an era of continuous developm
begun by Becquerel's discovery of radioactivity
1893. It is interesting to note, however, that du
this time, while scientists speculated on the pract
realization of the large amounts of energy stored i
materials, their main search was for new knowledg
give them a better understanding of the laws of nat
In 1940 the philosophy changed, and the drive for
end of speculation, to the practical realizatio

---

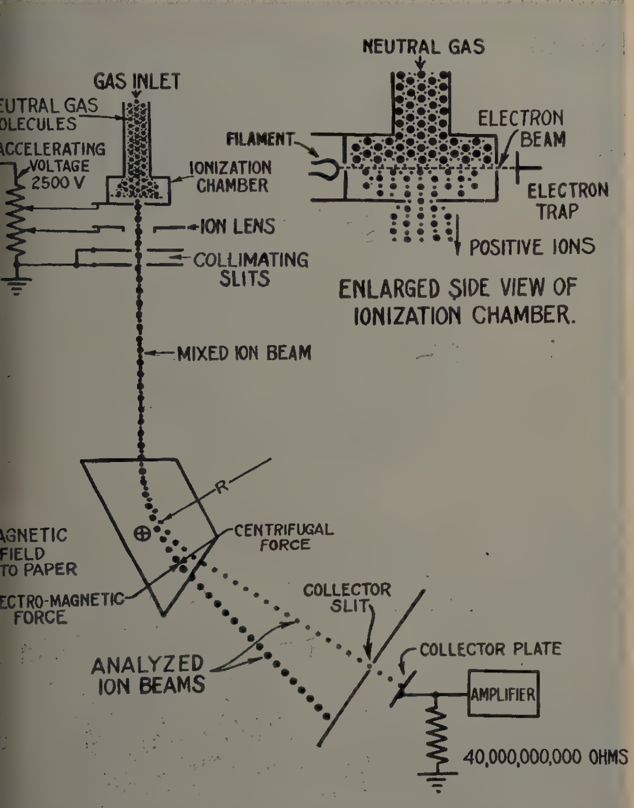
(1) Numbered references are listed at the end of the article.

ories in the form of an atom bomb, became pre-emi- t in the minds of many research teams.⑵

ic Principles

n what way, then, was the new knowledge gained m measurements made by mass spectrometry of ue in both searches?

et us look for a moment at the principles on which ny mass spectrometers of today depend. A hetero- eous beam of ions, formed by the impact of electrons neutral molecules, is separated into individual beams, h containing ions of only one specific mass. The mation of the electron beam, the production of a table mixed-ion beam, and its separation into ion ms of unique mass will be described later in this icle. It is sufficient to state here that in the segrega- n of the ions those of mass m_1 are separated from ose of mass m_2, the latter in turn being separated m m_3, and so on, with mass m_{n-1} being separated hin the limits of resolution from m_n. It was this que property which made the mass spectrometer h a valuable tool in the early search for knowledge of structure of the atom, and later in the release of energy contained within the nucleus.



ig. 1. Schematic diagram showing the principle of operation of a sector- pe mass spectrometer

omic Structure

n order to understand more fully this important tribution, some knowledge of the fundamental ucture of the atom is necessary. The heaviest part of atom is a very small core, known as the nucleus, ich is electrically charged in the positive sense. It thus forms a center of attraction for the negative electrons circling in their respective orbits around it. For example, in hydrogen there is one positive charge, or proton, and one electron; in sodium there are eleven electrons and eleven protons. This charge on the nucleus is the atomic number, which for hydrogen is 1 and for sodium is 11. Since all chemical changes are due to changes in the arrangement and motion of the outer, or valence, electrons, it is the atomic number which determines the chemical behavior of an element.

As yet, however, there is an unexplained anomaly: an atom of sodium weighs 23 times the hydrogen atom; yet there are only 11 protrons in the nucleus, as evidenced by the atomic number 11. The discovery of the neutron by Chadwick in 1932 offered a logical explanation. The neutron is almost of the same weight as the proton, and as its name implies, has no charge. The apparent discrepancy in sodium, as indeed with modifications in all the elements, can therefore be explained by a nucleus consisting of 11 protons and 12 neutrons, giving an atomic weight of 23 and an atomic number of 11.

In earlier days chemists had argued that all elements had an atomic weight that was an exact multiple of that of hydrogen. As measurements improved and new knowledge was gained, evidence was gathered that showed the rule to be broken in many cases. These facts, together with some of those found in the relations among certain of the radioactive elements, brought forward the hypothesis of Soddy in 1911, that within an element some atoms might have weights different from those of other atoms within the same element, while behaving chemically the same. Such atoms he called isotopes. Since they behave the same chemically, the number of electrons, and therefore the number of protons, must be the same in each. The difference in weight must then be due to a difference in the number of neutrons.

Proof of this, and therefore of the existence of such isotopes, was eminently demonstrated by Aston with his mass spectrograph. Other work⑶ followed rapidly—by Dempster, Bainbridge, Jordan, and Mattauch; and then Nier in 1940 performed his work in heavy isotopes, using a sector-type mass spectrometer. The instrument developed by the latter also played a vital part in the greater search—that for the release of nuclear energy.

Operation

FIGS. 1 and 2 show respectively a schematic diagram representing the operation of a sector-type instrument and an installation of the equipment. The gaseous mixture is introduced into the ion chamber through a molecular leak at a suitable pressure obtained after successive expansions, usually from atmospheric pressure. The neutral molecules are bombarded by a magnetically collimated beam of electrons whose energy is such as to ensure the formation of positive ions of all species of molecules that are contained in the original sample.

The ions thus formed have essentially zero energy. They are accelerated through 2000 volts and reduced to a fine ribbon by means of successive plates and slits in the ion source. The emergent beam is a heterogeneous mixture of all components of the original gas. Upon entering the d-c magnetic field the beam is separated, as mentioned earlier, into the individual beams, each containing ions of only one specific mass. This is also in accordance with the fundamental equation expressing the relation between the mass-to-charge ratio, the radius of curvature of the tube R, and the magnetic and electric fields H and V, thus

$$\frac{m}{e} = K \frac{H^2 R^2}{V}$$

In a given tube the radius of curvature is fixed, and therefore by varying H or V the separated beams of ions can in effect be swept as in a cathode-ray oscilloscope. A collector slit suitably designed and positioned will select in turn masses m_1 to m_n, as the values of field successively satisfy the equation. As the beams impinge on a plate that is coupled to a d-c amplifier through a high impedance to ground, ion currents can be measured and recorded. A plot of these ion currents against field strength is a mass spectrum. The ion current is a measure of the quantity of the components of the gas; and the field is a measure of their respective masses.

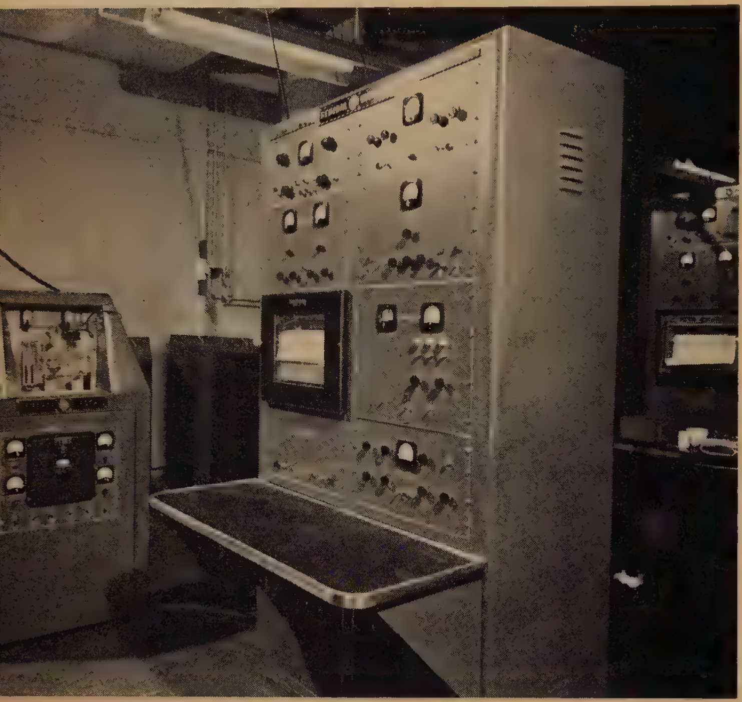


Fig. 2. Sector-type mass-spectrometer equipment

Three versions of the mass spectrometer have found wide application in the problem of the release of nuclear energy.

Leak Detection

In the first and most simple version, both the electric and magnetic fields are held constant and the other
instrument parameters are so chosen that, w
limits, the spectrometer is sensitive only to hel
Any gas other than helium entering the spectrom
would produce no signal. Such an arrangement is
nently suitable for leak detection. The vessel to be
checked is first exhausted, and then coupled thr
suitable valving to the mass spectrometer. Areas w
leakage is suspected, such as seams and joints,
probed with a fine jet of helium. A leak would a
the helium to enter the vessel and hence the
spectrometer, thus producing a signal which w
serve to indicate the presence of the leak. Heliu
chosen as a probing medium because (1) it does
occur to any extent in air or other gases, (2) it ca
readily pumped out of the test equipment, (3) it
not contaminate the system, (4) it is readily avail
and (5) it is of low molecular weight.

The development of leak-detection technic
especially those involving the use of the mass-spect
eter leak detector, are regarded as one of the m
engineering contributions in the separation of U^{23}
the gaseous-diffusion process.(4) The process speci
tions were most exacting, the volume large, and
working pressure so low that a greater degree of ti
ness was required than had yet been achieved in
commercial plant. The selection of the mass spectr
eter as the basic leak-testing instrument, and
development of leak-detection techniques made pos
a fourfold improvement in the process specificati
With such a high recommendation it is no sur
that the mass spectrometer is finding wide us
modern industry as a leak-detection equipment.

Recording Mass Spectrometer

The second version of the mass spectrometer was
recording mass spectrometer,(4) used for making
tinuous analyses of the process-gas stream in
gaseous-diffusion process. Before selecting the
spectrometer for this task, all known and new meth
were considered. The choice of the spectrometer
based essentially on the following four factors:

(1). As previously described, its sensitivity
to mass makes possible the determination of
quantity of each component in the process strea

(2). The quantity of gas consumed is neglig
small. This was extremely important because of
high monetary value of the material to be analy

(3). Any change in composition of the gas str
would be recorded almost instantly

(4). The principal components of the gas str
can readily be selected and the ion currents
responding to their quantities continuously and a
matically recorded.

In this mass spectrometer the magnetic field is
stant, and supplied by means of an alnico magnet
appropriately designed pole pieces. Masses are effect
ly swept by varying the value of ion-accelerating
age. While this could be done continuously, it was
particularly suitable for application to the prob

ler consideration, except when a complete analysis all impurities in the sample stream was desired. ther, the values of accelerating voltage corresponding those masses desired in the analysis of the gas were omatically selected in sequence and repeated at ervals. The ion current values were continuously plified and recorded. Special gas-inlet systems were essary, for which details have been recorded elseere.(4)

he recording mass spectrometer found eminent apation in the continuous analyses of certain impuri- in the process stream of uranium hexafluoride. was found that, with suitable calibration, gas contrations could be measured accurately to approxitely five percent of the reading; this has been conerably improved since. Changes in composition of gas stream were recorded within 60 seconds of their urrence. Consumption of uranium hexafluoride per trument was, on the average, less than 40 milligrams h day.

he contribution of this mass spectrometer to the mate release of nuclear energy is thus also seen to an important one.

alytical Mass Spectrometer

he third and final type of mass spectrometer, which applied to problems in the gaseous-diffusion proc- was the analytical mass spectrometer. In this many refinements were made in the tube: its source and collector, the analyzing magnetic field, the various electronic supplies. It was thus pose to obtain very high sensitivity and to cover a e mass range, yet still distinguish one mass from ther throughout the spectrum. Mass selection in case was done by continuously varying the magic field, the current to the coils of an electromagnet ig supplied and controlled electronically.

ecause of security restrictions, little is published he particular applications of this device. However, le such great effort was being made in applying the ss spectrometer to various phases of one particular blem, the value of its unique properties was being lored in other vast, important industries—those in micals and oil.

Vashburn,(5) Hipple,(6) and others showed that a ture of vapors or liquids could be analyzed, proed that certain requirements were observed in deing the gas-handling system. These requirements inled: constant temperature in the ionization region; uction of surface effects to the minimum; negligible nges in gas pressure in the ionization chamber due changes in pumping speed of the diffusion pump; vision that gases striking any hot metal surfaces ild not re-enter the ionization region; and maintece of the relative partial pressures of components gaseous mixture at the same intensity in the ionization chamber as in the original mixture. Under this condition the ions produced from each component, ing independently through the spectrometer, are ffected by the other components. Space-charge effects being negligible, linear superposition of the mass spectrum of each component results in the mass spectrum of the mixture.

Method of Operation

The analysis of a mixture of gases by means of the mass spectrometer may be performed in three steps, after the spectrum of the mixture is obtained. First, this spectrum is broken down into the component spectra of which it is made. In the second step, calibration spectra are obtained from pure samples of the components in the mixture. It will be realized that, with use, a library of calibration spectra will be compiled and the necessity for obtaining these spectra for each mixture will be reduced. The final step is to determine, by means of the solution of certain simultaneous linear equations, the composition of the mixture from the magnitudes of these component spectra and their calibrations.

This is one method that is suitable for the analysis of complex mixtures; and with the advent of such methods, together with improvements in amplification methods and the like, the use of mass spectrometry in the oil and chemical industries was quickly expanded. Further fields of application, which have been dealt with elsewhere,(5) are the study of the kinetics of chemical reactions, the use of appearance potentials for the determination of bond strengths, analysis by isotope-dilution methods, and isotope-ratio studies in the medical field. Future emphasis seems to be on the use of mass spectrometry for process control.

Fields of Application

In the fields of chemical analysis and process control, recent years have seen many attempts to provide new and improved methods for accurately determining the qualitative and quantitative composition of gaseous and/or liquid mixtures. Numerous physical methods employing the use of refractive indices, densities, and various excitational and optical phenomena have been devised. Infrared and ultraviolet absorption and the Raman effect have been found useful in the examination of many of the simpler mixtures, and have been proved very satisfactory in this work.

All of these methods suffer from rather severe limitations, either because of their very nature or because of restrictive practical considerations. The most versatile of all those mentioned is the infrared spectrometer, and here again one may not carry the technique to the analysis of hydrocarbon mixtures containing higher than C_6 hydrocarbons if laborious and time-consuming operations are to be avoided.

By contrast, in the present state of the art, the mass spectrometer can be generally extended to all mixtures whose components are fully vaporized at a pressure of 20 to 40 microns at normal temperature. This range is easily extended many fold by the simple expediency of raising the temperature of the inlet and analyzing regions to a point limited only by the thermal properties of the materials used in the construction of the affected parts. Hydrocarbon mixtures of molecular weights as high as 600 have been analyzed,(7) while the separation of a dozen or more components is common practice.

The clarity of the spectral data available from the mass spectrometer is at once evident upon comparison with the spectrum obtained from the optical methods previously mentioned. Here one is measuring by electronic means a fundamental unit—that is, mass. One rather serious drawback, however, which until recently has seemed to place a limit on the scope of applications for the mass spectrometer, is the high initial cost of the instrument in its conventional commercial form.

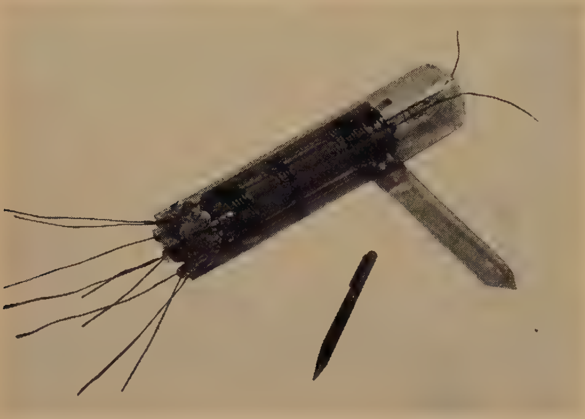


Fig. 3. Tube of a three-stage high-frequency mass spectrometer

Many industrial fields to which the methods of mass spectrometry are appealing do not require the wide range of mass separation and general over-all stability and flexibility which are prime requisites of an analytical instrument. An example can be made of mass-spectrometer type leak detector, which has given wide acceptance by industry.

High-frequency Mass Spectrometers

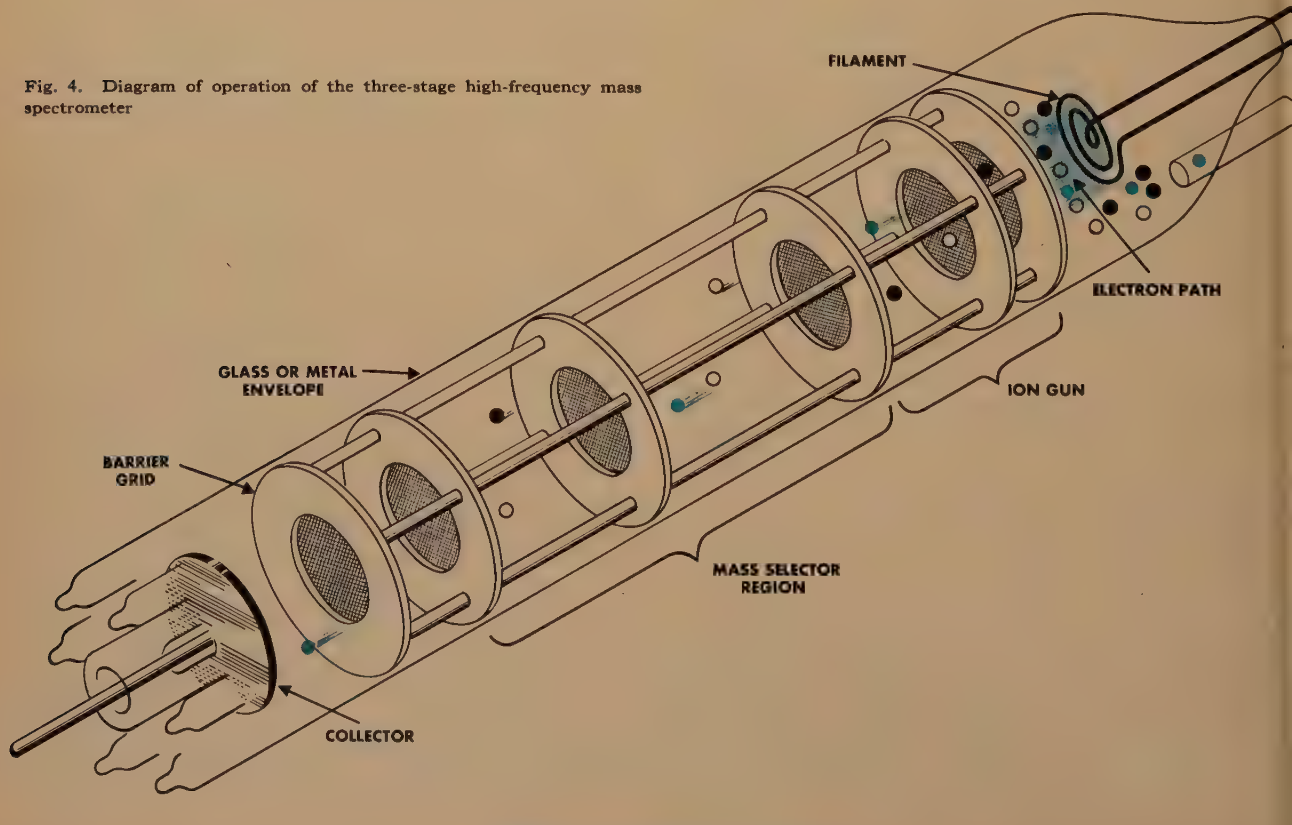
The recent advent of what may be referred t high-frequency mass spectrometers may largely a the outlook for mass-spectrometer application. offering the possibility of meeting the demand f relatively low-cost instrument of limited mass r without losing any of the fundamental advantage the general mass-spectrometric method, these new struments may soon play an important role in indust processes.

Several instruments have been described might fall into the general category of high-freque mass spectrometers. Of these, at least two have gressed through the development stage to such a p that commercial equipment is feasible. The opera of these two instruments will be described briefl what follows.

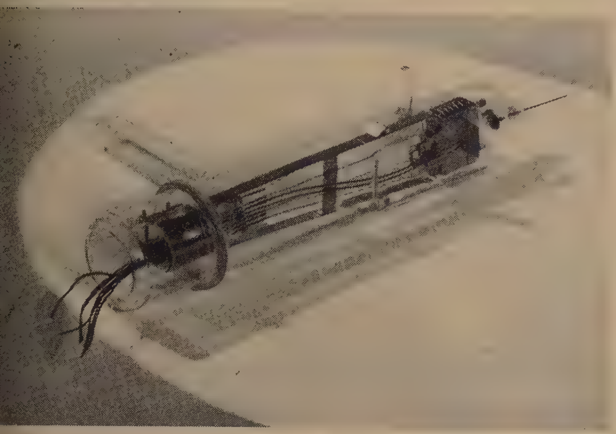
Fig. 3 shows a photograph of the three-stage h frequency mass-spectrometer tube described by B net;(8) a pictorial representation of the principles volved in its operation is shown in Fig. 4. For purp of illustration, the tube can be best described by re ence to three distinct sections: (a) the electron g (b) the high-frequency mass selector, (c) the ion lector.

Ions are formed by bombarding neutral molec with electrons of the desired energy. After the ions formed, they are accelerated into the mass discrim tor, where they are acted upon by a periodically var

Fig. 4. Diagram of operation of the three-stage high-frequency mass spectrometer



tric field. If the physical period of the ions in the ctor is, because of their initial energy, the same as period of the driving voltage applied to the selector hat is, if the ion is "phased"—it will attain energy icient to overcome a d-c barrier potential and be ected. Ions of a different physical period will be respondingly discriminated against, and hence can- gain the energy required to pass through the barrier.



g. 5. Resonance phenomena are utilized by this high-frequency mass ectrometer

he inherent high sensitivity of this tube, and the antage of requiring no magnetic field, is balanced the relatively low resolution attainable commen- ate with physical length. The resolution is theoreti- y independent of the mass being collected.

high-frequency mass spectrometer(9) utilizing nance phenomena to separate ions of differing s is shown in FIGS. 5 and 6. This tube employs ssed magnetic and periodically varying electric ls. When the natural period of a given mass ticle in the magnetic field is equal to the period of driving voltage, resonance occurs. The particle tinuously gains energy, and hence will follow a al path of ever-increasing radius until it attains radial displacement required to be collected. Parti- of other masses suffer discrimination, because of r inability to gain sufficient energy to reach the ector before they lose their phase relative to the tric field. The ion-resonance mass spectrometer ribed in the preceding paragraphs has the advan- of very high resolution, particularly in the low s range. The resolution varies inversely with the s, with values as high as 1 part in 50,000 at H_2 g reported by Hipple(9) with use of an instrument odying the principles set forth here. The sensi- y is comparable with that generally associated mass-spectrometer methods.

appears that the applications for both of these spectrometers may be considerable. The relatively ll size of each is a decided advantage where space importance. The tube shown in FIG. 3 may find use where the additional weight of a magnet is to be ded. In the use of these tubes, simplification and condensation of existing mass-spectrometer components and circuits may be possible, making for a more compact, lighter weight, and generally more rugged instrument.

Summary

There is a virtually unending array of processes and problems to which the mass spectrometer is uniquely adaptable or to which it offers simplification of existing techniques. The past 50 years have seen the mass spectrometer pass through a tremendous period of growth. From the laboratory apparatus of Thomson it has progressed until, today, it may be said that its range, when realized, greatly exceeds the possibilities of many other methods of analysis. Hence it can be said to be one of the most useful of all analytical tools.

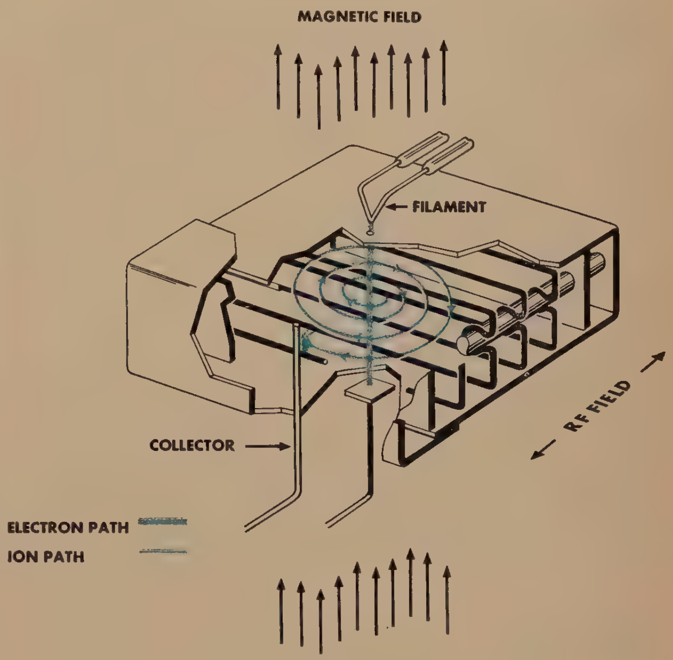


Fig. 6. Diagram of operation of the spectrometer shown in Fig. 5

References

(1)J. D. Stranathan: *The Particles of Modern Physics*, Blakiston Company, 1942.

(2)J. L. Crammer and R. E. Peierls, F. R. S. (Editors): *Atomic Energy*, Penguin Books Limited, Chapter 1.

(3)"A Short History of Isotopes and the Measurement of their Abundances," by E. B. Jordan and L. B. Young, *Journal of Applied Physics*, vol. 13, no. 9, Sept. 1942, pp. 526-538.

(4)Manson Benedict and Clarke Williams: *Engineering Developments in the Gaseous Diffusion Process*, McGraw-Hill Book Co., Inc., 1949.

(5)W. G. Berl: *Physical Methods in Chemical Analysis*, Academic Press, Inc., vol. 1.

(6)"Gas Analyses with the Mass Spectrometer," by J. A. Hipple, *Journal of Applied Physics*, vol. 13, no. 9, September 1942, pp 551-560.

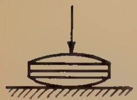
(7)"Mass Spectrometry of Heavy Hydrocarbons," by M. J. O'Neal, *Analytical Chemistry*, vol. 23, no. 6, June 1951, p. 830.

(8)"Radiofrequency Mass Spectrometer," by W. H. Bennett, *Journal of Applied Physics*, vol. 21, no. 2, February 1950, pp. 143-149.

(9)"The Measurement of e-M by Cyclotron Resonance," by H. Sommer, H. A. Thomas, and J. A. Hipple, *Physical Review*, vol. 82, no. 5, June 1, 1951, pp. 697-702.

MINIATURE FORCE-AND-PRESSURE CELLS

The developmental considerations including size, shape, material, surface finish, and lubrication of miniature force cells—designed to be a valuable tool in the measurement of force and pressure



By H. F. RONDEAU
Locomotive and Car Equipment Laboratory
General Electric Company

"WE WANT a force cell for measuring loads up to 5000 lb or more—and oh, yes! It should fit into a space one inch in diameter by five-sixteenths of an inch deep, have linear characteristics, a response independent of frequency to several hundred cycles per second, and it should be inexpensive." Such a request, with the usual intriguing requirements, prompted the development of several diaphragm-type force-and-pressure cells.

The Force Cell

With simplicity of design as the ultimate goal, the 5000-lb-load force cell took the shape of a button (Fig. 1). The slight radius of curvature on the upper side was to aid in centering the point of load application. Some shape of recess on the underside was to provide space for the sensing element—a wire strain gage.

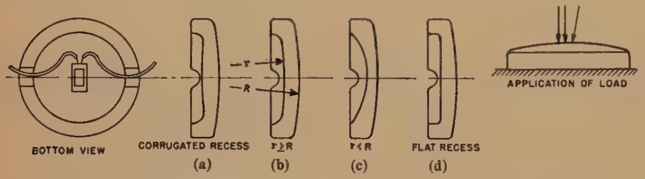


Fig. 1. Suggested cross sections of button-type force cells

Even though the general design had been established, the major problems remained to be solved. Aside from a selection of cell material and hardness, many compromises were necessary. The cell cross section in Fig. 1, indicates that section (*a*) is less sensitive than section (*c*). However, the latter cell is more sensitive to off-center forces and the direction of the applied force. Section (*b*) incorporates some advantages of (*a*) and (*c*), but tests showed the flat recess of (*d*) to be equally good. Being much easier to machine, it was chosen.

Another problem is friction. The annular area of contact on the lower surface of the button is the greatest offender. If the outer edge is radiused to form a circular line contact, the large contact stress will cause the cell to embed itself in the contact area. This condition will tend to aggravate itself and make it impossible to keep the cell in calibration. (Keep in mind during calibration that the surface upon which the gage rests is a part of the system.) If, in the other extreme, the annular contact area is made large so that there is no danger of embedding, the friction-restraining forces will prevent the cell from freely deforming under load. This hysteresis-like effect, which causes the calibration curves for increasing and decreasing loads to diffe shown in Fig. 2 (a). If space is available, the effec friction can be minimized by using two cells, as sh in Fig. 2 (b).

This development synopsis will serve to make any intending to build and experiment with the shape of button-type force cell aware of the impending proble

Button-type Force-cell Design

Tests of several developmental force cells made f different materials indicate that carbon tool steel good choice of cell material. Next, it is necessary select the cell shape. Since the cell volume is held minimum and the design load is high, it is desirabl choose a shape such that the safety factor will b maximum for the desired sensitivity. Two of developmental 5000-lb force-cell designs are show Fig. 3.

Because the cell is to be subjected to large stra it is important to radius all edges and remove all marks by polishing the entire surface. It is also ne

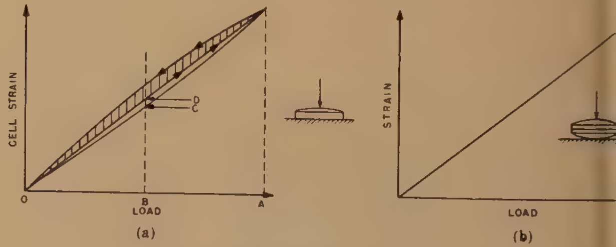


Fig. 2. Cell-load response characteristic curves

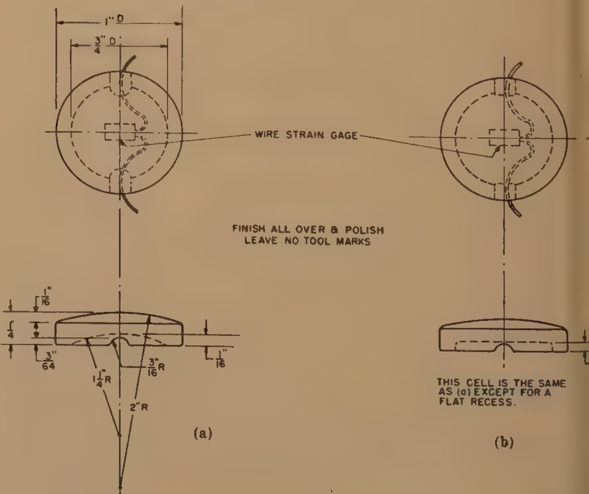


Fig. 3. Button-type force cells (5000-lb maximum load)

y to heat-treat the cell by hardening and drawing about 55 C Rockwell. The button should be polished ain after hardening. This will readily reveal any croscopic cracks which might otherwise be misstrued as oxide layer boundaries that result from the rdening process.

Vire strain-gage selection is largely a matter of availe recess area and application. Suitable size gages d on the cells shown in Fig. 3 are the AB-11 or A-7 e of SR-4 wire strain gage manufactured by the ldwin-Lima-Hamilton Corp. For extremely rugged plications, the Type AB-11 gage is suggested.

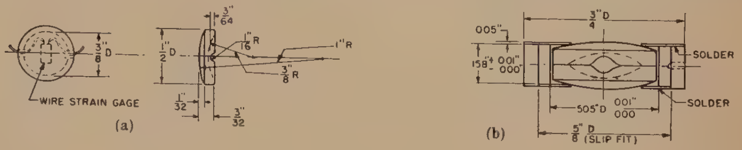


Fig. 4. (a) "Pee-wee" force cell (50-lb maximum load) (b) Two "Pee-wee" force cells held in place by cascading rings

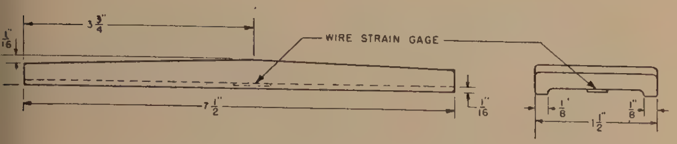


Fig. 5. Plate-type force cell (10,000-lb maximum load)

The removal of gage leads, unless done with extreme e, can be a serious source of trouble. It is suggested t, after trimming the gages to about $\frac{3}{16}$ in. by ⅜ in. l removing the excess gage backing from the leads dipping them into hot concentrated sulphuric acid, gage leads be reduced to about ⅛ in. in length. all, flexible, insulated leads should be soldered to gage leads and the combination cemented to the lerside of the cell. Precautions should be taken to vent the gage wire and flexible lead junctions from ching the plane of the bottom of the cell. This is essary to prevent the wire strain gage from becomshort-circuited by the surface upon which the gage ts. After the gage has been properly cemented and ed, it is advisable to apply a liberal coating of nent to the recessed area on the underside of the cell hold the lead wires securely.

ce-cell Calibration

t is important to remember that for most accurate ults the force cell should be calibrated on the face with which it is to be used. If the allotted cell ce is about 50 percent greater than the force cell, s advisable to place a thin, tenacious wear pad— h as Motung steel or manganese steel—between the lerside of the gage and the work surface. This will vent the cell from gouging into the work. It also kes possible the calibration of the force cell and wear l as an integral unit away from the work.

The effect of friction between the cell and the surface on which it rests is sharply reflected in the loadain characteristic curve. If surface friction were ligible, the characteristic curve would be dependent y upon the geometry and the elastic properties of cell. Also, the increasing load-strain curve would be ncident with the decreasing load curve; that is, the teresis-like effect would not be present. In the presence of friction, the shape of the characteristic curve is altered and a space occurs between the "up and down" load curves.

It is desirable to select a cell shape, surface finish, and lubricant such that a duplicate linear characteristic curve with minimum hysteresis-like results. This places a heavy demand upon the surface preparation. Of several lubricants tested, the most satisfactory was molybdenum disulphide. If space permits, use of two gages, such as in the scheme shown in Fig. 2 (b), is desirable because the effect of friction is nullified.

The present design of force cell is not temperature compensated; thus its application limitations are obvious. In many cases where the temperature change is negligible over the interval of measurement, this is not a serious problem. Further work may reveal that a temperature-compensating gage can be cemented along the outer periphery of the cell.

Other Force-cell Designs

"Pee-Wee" Force Cell

The need for a 50-lb-load force cell of extremely small dimensions was satisfied by a button-type cell patterned after the 5000-lb force cell. It is the smallest cell of this type (Fig. 4(a)) with which we have experimented. It was also made from carbon tool steel and hardened to 55 C Rockwell. A 60-ohm Type A-19 SR-4 wire strain gage was cemented to the underside. This cell gave a nearly linear characteristic curve similar to that shown in Fig. 2 (a).

It was found that this cell can be used to measure dynamic forces at frequencies up to about 900 cps. It has the disadvantage, however, of being extremely sensitive to the direction of the force applied to the top of the cell, as well as to the shift of the point of application of the load. It is believed that these conditions can be somewhat improved by using a flat recess instead of the ⅜ in. radius. Also, if there is available space, it is desirable to combine two cells in the cascading-ring as shown in Fig. 4 (b).

Plate-type Force Cell for Severe Applications

This cell design resulted from the need for a gage to measure forces up to 10,000 lb between the equalizer bar and journal box of a locomotive truck. The only available space is about 1½ in. wide by 7½ in. long and ½ in. deep. The resulting force cell is shown in Fig. 5.

This plate-type cell also has a load-strain curve similar to that shown in Fig. 2 (a). However, because of the excessive load and large cell-work area, surface lubrication is of prime importance. Table I shows the results obtained with several surface coatings. Deviation from linearity was defined as $(DC/BD) \times 100$ percent where B is ½ the maximum cell load OA, as shown in FIG. 2(a), and C is the intersection of BD and a straight line drawn from the origin of the characteristic curve to the tip of the curve. The hysteresis-loop area, shown cross-hatched in FIG. 2 (a), was assumed to be unity for a dry (nonlubricated) cell-work surface. The hysteresis-loop area for other surface lubricants is given as a fraction of the dry surface-loop area.

Based on these data, molybdenum disulphide was concluded to be the best surface lubricant tested, since the resulting characteristic curve was exceptionally linear.

Simple Fluid Pressure Cell

A simple fail-safe, dependable, and compact diaphragm-type pressure cell can be built into a conventional pipe plug. FIG. 6 shows the details of a 100-psi cell. The sensing element consists of a 13 mil thick phosphor-bronze diaphragm upon which is cemented a 60-ohm Type A-19 wire strain gage. The diaphragm is held in place by a leak-proof seal formed by rolling a thin layer of metal over its edge. The strain-gage connections are removed by two pins pressed into Textolite* plug which is, in turn, pressed and cement into the hollowed-out pipe plug.

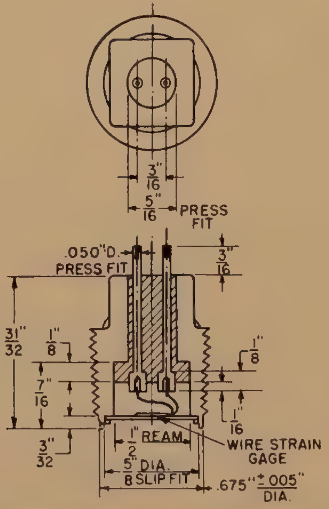


Fig. 6. Plan and section drawing of miniature fluid pressure cell (static and dynamic pressures up to 100 psi)

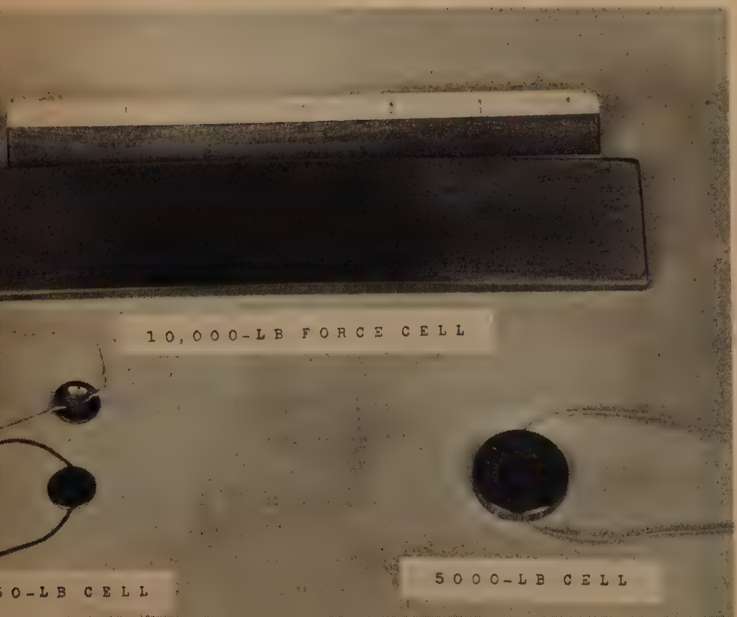


Fig. 7. Comparative sizes of three force cells

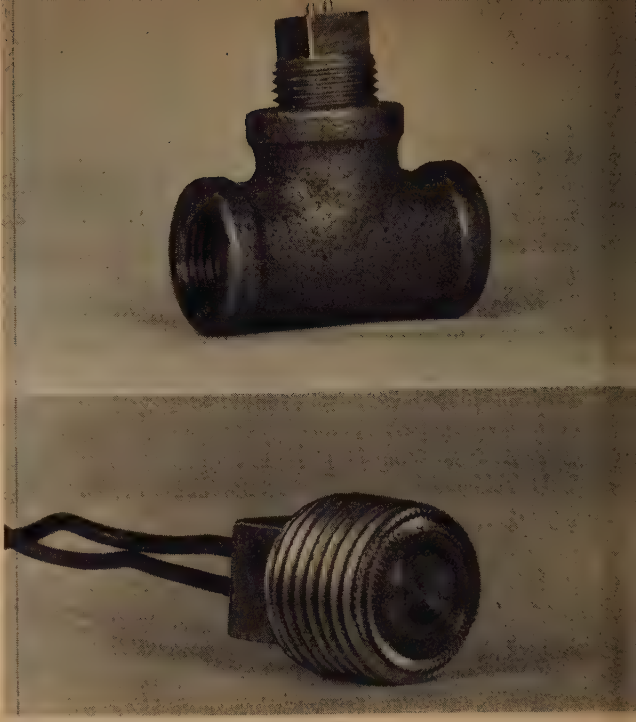


Fig. 8. Pressure cell for installation in a pipe tee

The cell has a very linear pressure-strain charact istic curve; it can be used to measure static pressur as well as dynamic pressures at frequencies up approximately 400 cps or higher. Moreover, it le itself particularly well to measuring pipe-line pressur in which case it is screwed into a pipe-tee. It is a useful in measuring tank pressures where it can screwed into a boss on the tank.

TABLE I: SURFACE LUBRICATION

Force-cell Work-surface Lubricant	Percent Deviation From Linearity	Relative Friction Hysteresis-loop Ar
None (Dry)	6.3	1.0
Graphite	3.0	0.82
Grease	9.5	0.55
White Lead	2.4	0.67
Molybdenum Disulphide	1.7	0.58

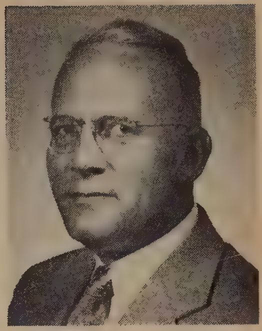
Summary

This article describes a new series of force-and-press cells (FIGS. 7 and 8) unique for their compactn They are simple in construction, have reasonably lin characteristic curves, and can be built in the aver laboratory at a low cost. In time, each of the quali mentioned can be much improved because these c are still in the developmental stage. It is hoped t others may further this development by exploring a tional cell shapes and surface lubricants. In whate work may be done, it is important to remember t the cell and the surface upon which it rests comp the measurement system, and therefore should alw be considered together. Further research and exp ment will help transform this development int valuable tool for measuring of force and pressure.

---

*Reg. trade-mark of General Electric Company.

NEW LIGHTING MEASUREMENTS LABORATORY AT NELA PARK



Wentworth M. Potter

Facilities highly flexible as to room sizes, proportions, reflectance of surfaces and type of lighting system, and mechanized measuring equipment, expedite setup and tests for lighting design data

By WENTWORTH M. POTTER
Lamp Division, General Electric Company

ADEQUATE selection and design of lighting systems involves the predetermination of results in lumination and brightness for a very wide range of oom conditions and installation practice.

The pioneer work of Harrison and Anderson(1) more han 30 years ago provided the basic data for quantitaive lighting design used throughout the world. Their oom-index method and utilization data supplied well he needs of general lighting practice with filament imps and luminaires, as conventionally applied for niform illumination on a horizontal plane.

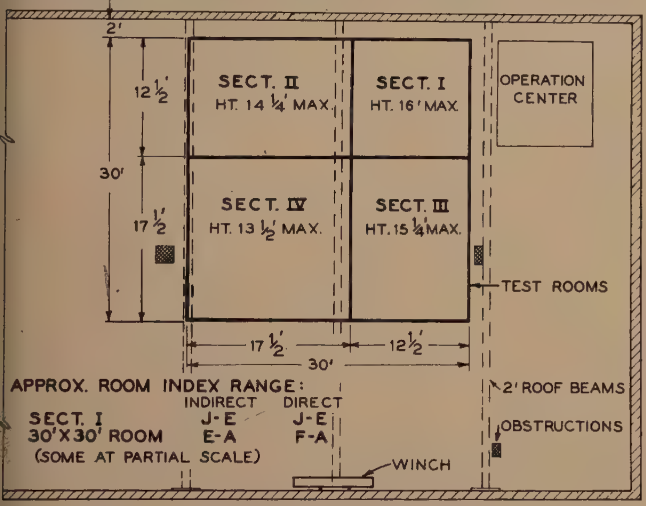


Fig. 1. General plan of lighting measurements laboratory affords a wide range of room proportions, with many at full scale. Sections can be connected for different shapes, or some dimensions modified. Smallest room (Section I) located for maximum ceiling height to obtain one extreme of proportion

During the intervening years, the lighting art has een enriched with many new resources—with lamps of adically different dimensions and characteristics; with ghting elements differing greatly in extent and brightess; and with new techniques and trends in practice. ome of these are concerned with the brightness pattern resented by a room and its effect on visual comfort, fficiency, and appearance. Some involve more interestng form and placement, or larger size of lighting elenents, and frequently their physical integration in the tructure. As a result, revisions of the system or changes n illumination or brightness values become relatively uch more costly, even impracticable. Yet needed ata—tested and comprehensive—for predetermining esults are often not available.

The Harrison-Anderson tables have been extrapolated(2) to some degree but with increasing uncertainty, and they did not apply originally for lighting elements of the larger dimensions, for placements, nor for conditions of occupancy and appointments with reflectances often found today. Neither do they include any data on results of the important vertical or oblique planes. Also, more and more frequently one is interested in results in localized areas, and in the over-all contribution of supplementary lighting elements.

The interflectance method(3) of illumination and brightness calculation, based on mathematical analysis, has been an important help in filling gaps in lighting technology, but its usefulness could be extended by correlation with a wide range of actual test information.

Thus, there has been a need for highly flexible laboratory facilities to encompass a wide range of room sizes, proportions, shapes, and patterns of reflectance; of location, size, type, and candlepower distribution of lighting elements. These would expedite systematic basic studies and also provide for ready mock-up of individual situations of particular interest. Accordingly, a highly adaptable structure was designed; its steel channels and other parts are quickly demountable and may be reinstalled in other positions as required.

Equally flexible facilities, adaptable to measurements of illumination in any plane, and of brightness, were needed. Because the range of information desired is great, mechanization of the measurement process to conserve time became an objective.

General Plan of Test Rooms

The general plan (FIG. 1) is designed to utilize variable ceiling height and lateral dimensions to achieve a wide range of room proportions and several rectangular, as well as square, rooms. Dimensions up to 30 ft square permit ready changes in setup, yet, with the ceiling lowered, they provide proportions found in very large spaces. Moreover, many spaces are available at substantially full scale for subjective appraisals of comfort or appearance; ceiling height up to 13½ ft is available for even the largest room.

On the other hand, the ceiling may reach the top of the available space to provide the other extreme of room proportions with smaller rooms. The smallest square room with maximum ceiling height of 16 ft is shown in FIGS. 2 and 3; its 12½ ft dimensions were dictated by the desired range for smaller spaces and by

---

(1) Numbered references are listed at the end of the article.

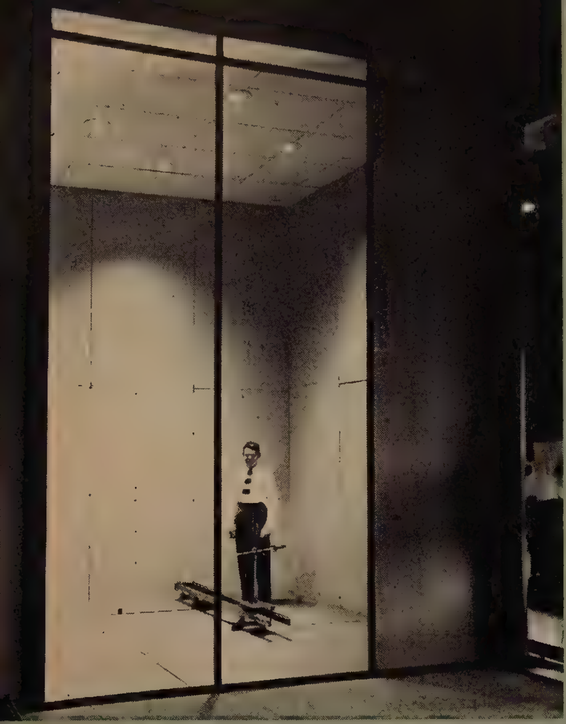


Fig. 2. Smallest square room (12½ ft by 12½ ft) of laboratory with two wall panels removed to show interior. Ceiling at maximum height of 16 ft

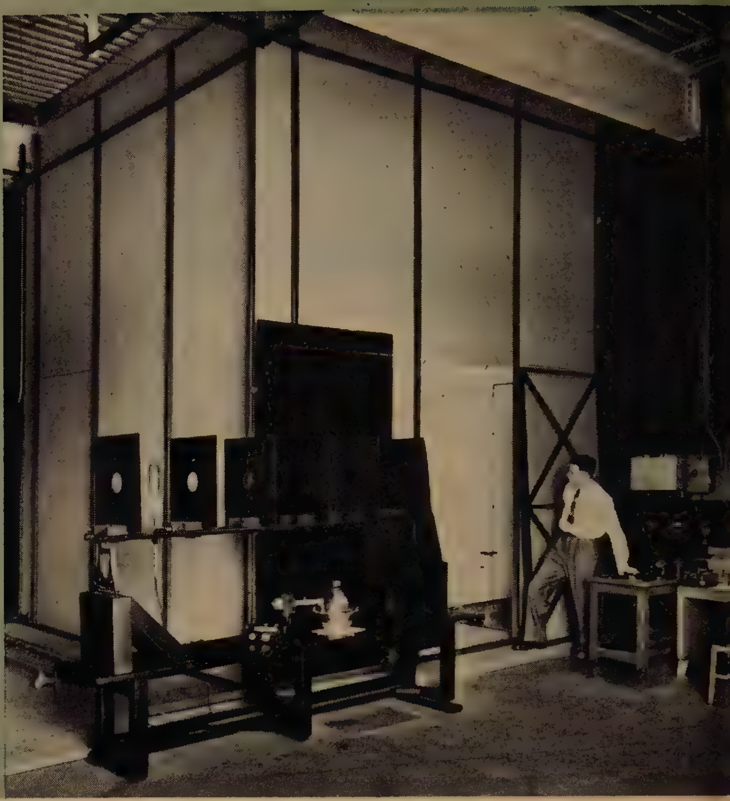


Fig. 3. Exterior view of room shown in Fig. 2. Bar photometer for calibration conveniently located. Operation center at right

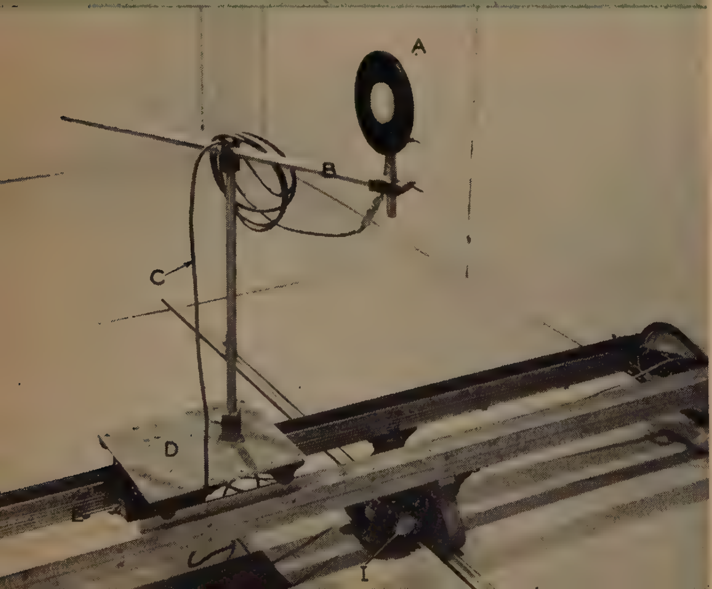
the lengths of fluorescent lamps and luminaires. Rows of 3-, 4-, or 6-ft lamps can be conveniently installed.

This plan avoids the limitations of working in miniature; a considerable range of proportions is available at both full and reduced scale. Thus, the effect of scale tests with full-size luminaires can be determined, and the usefulness of the various expressions for room proportions can be explored.

Ceilings. To support lighting elements and any desired ceiling construction, four demountable grids corresponding to the four sections of the general plan are provided. Each has two basic rigid members (light 6 in. by 1⅞ in. I-beams). Across these any required heavy steel channels are clamped. Lengths provic ½-in. wall clearance. Four wire ropes of the hoistin system, attached to the I-beams by stirrups, suppor each ceiling section and raise and lower it alone or i synchronism with connected adjacent sections.

Fig. 4. A test head shown on carriage and track assembly. Track and floor rails can be extended for scanning larger spaces

A: Test head
B: Brackets adjustable for height and angle of head
C: Shielded cable
D: Carriage
E: Carriage motor
F: Track
G: Bus bars
H: Rack
I: Track motor geared to
J: Floor rail with rack



Ceiling heights and, therefore, room proportions ar easily changed by the electric-hoisting system; grids ca be dropped to floor level, if desired. The uniform motio necessary for connected ceiling sections is provided b controlling all 16 ropes with a single heavy winch ceiling speed is about one inch per second. All ropes ar adjustable for leveling.

Ceiling surfaces, either opaque reflecting or transl cent, are supported by secondary structural membe attached to the grids. Transilluminated panels c ceilings of louvers or diffusing materials can be hun below a reflecting cavity and lamps. Conventiona luminaires can be readily installed and shifted abou Recessed types may penetrate the grid between beam

Walls. The wall structure consists of vertical ligl steel channels spaced as needed and clamped top an bottom to similar horizontal members. They suppo lightweight removable reflecting surfaces. Coves, va ances, or other elements can be attached, and actu doors or windows can be built-in or simulated.

Floor. Movable sections of 4-ft by 8-ft plywoo panels on light wood frames provide a level floor.

Reflecting Surfaces. For lightweight wall, ceilin and floor reflecting surfaces, sheets of double-face corrugated carton board have been used. These a finished with different reflectances on opposite side As required, patterns of varied reflectance and col can be obtained. Flanges supporting ceiling panels a covered with tape lacquered to match ceiling reflectanc

Photometric Equipment

Accuracy, flexibility, and adaptability to automatic ecording of results have been objectives in devising he equipment for measurement of illumination. Possibilities for automatic equipment for measurement of oom surface brightnesses are being studied.

Light-sensitive Cells. For accurate measurement of llumination, an essential characteristic of the receptor s a high order of cosine correction, or ability properly o evaluate light incident at all angles.(4) It is especially mportant with wide-distribution, large-size elements and high-reflectance walls, and in such measurements as of vertical or oblique-plane illumination where light from the principal sources is incident upon the cell at large angles from the normal.

A new type of test head with excellent cosine correction, particularly at high angles, has been used.(5) In this device, shown in FIG. 4, a disk barrier-layer light-sensitive element is used for uniform acceptance of light from all directions. Superposed on this element are a Wratten No. 102 filter for color correction and a selected neutral-density filter. The element and filters are mounted within a small turret of translucent methacrylate plastic. The test head includes also a black shield whose rim prevents acceptance of light from any point below the plane of the cell turret.

For the wide range of illumination values, two such test heads with different neutral filters are in use. Because adequate sensitivity of the recording apparatus is available, and because cells respond most accurately at low energy levels, one head has a filter of 1½ percent transmittance. The other head, for a lower range of values, is about 23 times as sensitive.

The Recorder. Signals from the test head are conducted by shielded cable to an automatic current recorder (FIG. 5) of the slidewire null type, with a 10-in. 100-division scale.(6) As the test head is moved in the room by means described below, this instrument records the illumination values in continuous curves on its rectangular co-ordinate strip-chart.

Sensitivity of the system is varied by using the several combinations of the three recorder ranges—with ratios of 1, 2, and 5—and the two test heads. With them, full-scale deflection can be produced by illumination values ranging from 2.5 to 250 foot-candles. For a similar test head without neutral filter, the same deflection would require only 0.8 foot-candles.

The speed of response of the instrument appears adequate for correct indication of high gradients in illumination at the selected speed of cell travel (1⅞ inches per second). Curves check closely against individual readings taken with stationary cells.

Linearity. Because corrections of plotted curves are impracticable if time is to be conserved, a high degree of linearity of the system is essential. Cell elements have been selected which, in combination with the recorder, provide closely linear response. The maximum error at any point on the scale is a small fraction of a division, and this is minimized by calibration at mid-scale. This characteristic is easily checked from time to time with the bar photometer located just outside the test room.

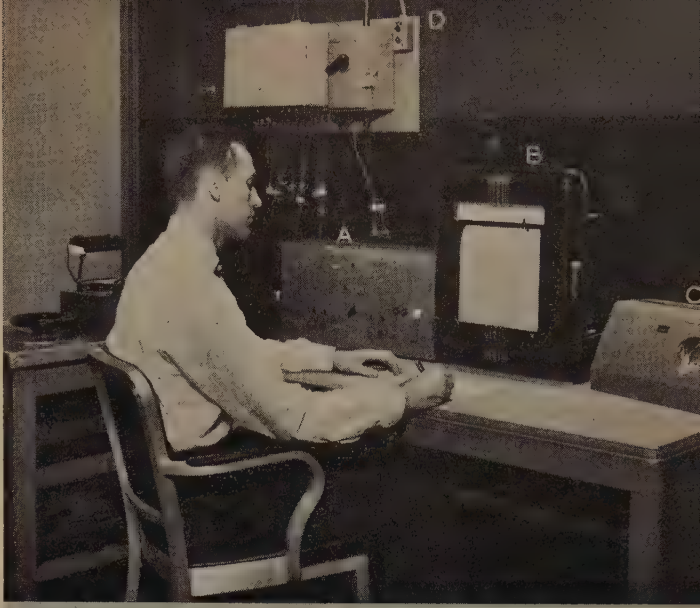


Fig. 5. Operation center including:
A: Control panel for scanning equipment, recorder, and integrator
B: Recorder
C: Integrator
D: Control button for ceiling hoisting system
Voltmeter and controls for test lamps, calibrating lamp and integrator circuits are shown at left

Calibration. The same bar photometer, so located that the cell need not be disconnected, is also used for calibrating the whole system. The cell is mounted thereon in a fixed position, carefully baffled, and illuminated by a carefully selected, seasoned, and rated 1000-watt T-20 C-13 filament clear-bulb lamp which is positioned at distances calculated to provide the foot-candle values needed for calibration of the various scales. Interim checks and adjustment of system response are afforded by standardization equipment contained in the recorder.

It has been found advisable to provide also a fixed-reference condition for occasional checks on the whole process of measurement for any one pattern of room reflectances. This consists of a single seasoned 500-watt T-20 inside-frosted bipost-base lamp which can be placed in a fixed, reproducible position at the center of the ceiling.

Control of Deflection. In some situations, high peaks of illumination occur; their corresponding deflections must be confined to the recorder scale. Means to this end include the changes in sensitivity described. However, when they cannot be handled by the least sensitive scale, voltage supplied to filament test lamps may be reduced provided the cell is color-corrected, the room surfaces are essentially nonselective, and the voltage-lumen characteristic of the lamps is known. The latter has been determined by placing the cell in a fixed position in the test room and recording relative deflections for different lamp voltages with all other conditions constant. Thus are derived factors determining actual lamp output at the voltage used during such tests. Normally, test lamps are operated at no more than 105 volts to conserve life, and they are photometered for output and distribution at that value.

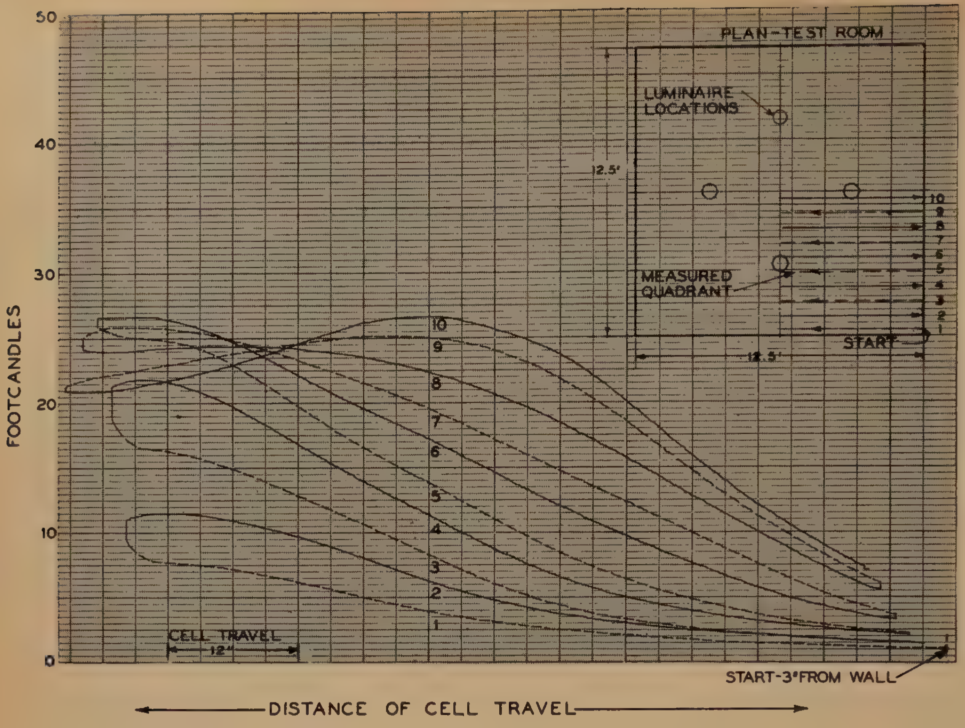


Fig. 6. Automatic test record of horizon illumination distribution in a quadrant o 12½ ft square room, of ratio 1.0 (Index I with surface reflectances: ceiling, 0.80; wal 0.50; floor, 0.19. Luminaires: recessed baffl downlights with 150-watt R-40 reflector flo lamps operated at 105 volts. Curves sh illumination along centers of 7½ in. stri 30 in. above floor. Average illumination, 1 foot-candles. Offsetting of curves is due known overtravel of recorder strip-cha Alternate dashed and solid lines (to facilita identification) are produced automatica by a device applied to the chart-dri mechanism

Control Equipment

Searching Mechanism. Continuous recording of data requires controlled scanning motion of the cell. For illumination measurements, this is provided by mounting the test head on a small carriage which traverses a chosen space upon a track. This track in turn moves transversely upon floor rails.

The carriage rises only 10¼ in. above the floor to facilitate measurement in various planes and provides freedom in mounting the test heads. Both carriage and track are propelled by their own synchronous motors geared to racks and controlled by adjustable limit switches. An ingenious circuit provides either manual control of carriage and track by push button at the operation center or a predetermined automatic cycle for operating both. The cell can be moved to any position, a single-traverse curve recorded, a peak value searched out, or a complete test taken without the operator entering the room. In automatic scanning of a space, the cell may start in a corner and traverse a strip of area along the wall. At a chosen point, the cell stops while the track moves laterally a distance determined by preset rail cams; then it reverses and continues to make these consecutive traverses in opposite directions.

Motion of the recorder strip chart is controlled by the same circuit during operation. The driving motor moves and stops the chart in synchronism with the motion of the cell and carriage, reversing direction to conserve paper. The resulting curves are at once available for averaging, for calculation of delivered lumens and coefficients of utilization, and for studies of distribution. An example of such an automatic recording is shown in Fig. 6.

Voltage Control. All photometric equipment and lamps are operated on 60-cycle alternating current regulated by automatic voltage stabilizers. (Because the wave is not of sine form, calibrating and test lamps a photometered in another laboratory using the sam stabilizers and the same voltmeter used here.)

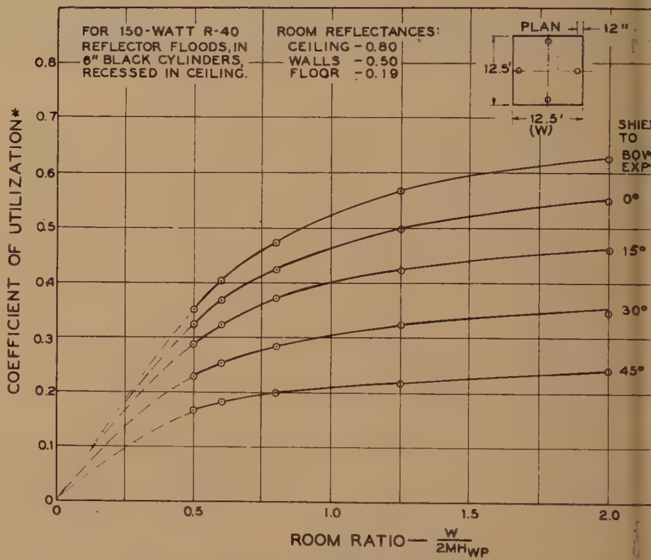


Fig. 7. Curves show measured coefficients of utilization for one location of direct-lighting units of 6 in. diameter. Each curve applies for a different shielding angle measured tangent to the lamp bulb, and hence for a different luminaire candlepower distribution. As shielding increases, distribution becomes narrower and output of luminaire is reduced. Abscissa is the measure of room proportions; MH_{WP} is the height of units above plane of measurement

For tests and calibration, variable autotransforme suitably connected provide both coarse and fi adjustment of voltage. For filament test lamps, volta to each is adjusted individually for equal lumen outp to preserve symmetry in the test room.

Automatic Integration of Curves

For the purpose of eliminating the considerable tim involved in averaging of recorded curves, thus great speed checking, analysis, and production of data, iere was devised an automatic instrument which itegrates the curves simultaneously with recording. FIG. 5). The essential part of this instrument is a iodified watthour-meter element without gears or indi-ating dials. It is operated upon a separate stabilized oltage circuit held at 110.5 volts. The meter current oil carries a constant load.

---

*Coefficients express light-flux received on the horizontal plane of measur ment as a fraction of the initial output of a general-service lamp of the sa wattage.

The integrator is controlled in two ways: (1) by earching-mechanism control-circuit relays so that it perates only when the test-head carriage is in motion n its track; and (2) by the recorder as to speed of otation of the element disk. The latter is accomplished hrough a potentiometer so connected to the recorder ndicating mechanism that contact movement is pro-ortional to deflection. As deflection changes, varying oltage is impressed upon the watthour-meter voltage oil, varying the speed of disk rotation.

The disk itself has accurately spaced holes near its eriphery. As it rotates, these holes allow light from a nall filament lamp to energize a small phototube and s amplifier circuit. This in turn actuates a solenoid ounter. During a test, counts are registered at speeds roportional to illumination on the cell, and the total available the instant cell motion ceases. This figure is uickly convertible, with the proper constants, to verage illumination or to total lumens incident upon e plane of measurement. The latter value, divided by ource output in lumens, gives the coefficient of utiliza-on; such coefficients are the basis of the lumen method f lighting design. Values of coefficients so obtained are lotted in FIG. 7.

The constant for calculating average foot-candles epends upon the counts registered per division of eflection for unit distance of cell travel, the total istance traversed and the recorder-scale factor; for imens, the area scanned is also a factor. They are stablished and checked by carefully averaging the rdinates of representative recorded curves, calculating oot-candles and total lumens, and relating them to ounts registered.

As indicated in Table I, the results of this integration rocess are excellent for most curves exhibiting con-derable and changing deflection, for the linearity urve of the integrator is averaged. However, at very w deflections, the departures from linearity may be latively large, and may appear in opposite directions r small differences in deflection. Hence, a traverse ith constant low deflection may exhibit a substantial ror in counts; such are avoided insofar as possible by ale changes between traverses. With still better curacy over the whole scale as a goal, and to eliminate e speed limitation of the solenoid counter, other rms of integrator are under study.

ther Tests

Of equal importance in the development of design ata—such as coefficients of utilization—is exact nowledge of the light output of lamps and lighting ements used in the test rooms. The laboratory described here is designed to measure the over-all lighting results, but the sources themselves must be carefully measured initially and frequently checked. Considerable groups of seasoned lamps must be tested alone and in the variety of luminaires to be employed, their light output calculated by zones and the data carefully analyzed as to whether the light distribution is representative and consistent. The semiautomatic distribution photometers developed by G. R. Baumgartner[(6)] have greatly facilitated actual testing. There is a further need: An accurate polar-curve integrator and lumen counter to eliminate the considerable and tedious work of calculation.

TABLE I

COMPARISON OF AUTOMATIC INTEGRATOR RESULTS WITH INTEGRATION BY AVERAGING ORDINATES*

Integrator Check No.	Lumens Delivered By Automatic Integrator Count	Lumens Delivered By Averaged Ordinates**	Percent Error of Integrator
1	2750	2726	+0.88
2	1959	1964	−0.25
3	586	586	......
4	664	663	+0.15
5	604	607	−0.49
6	509	506	+0.59
7	1004	1004	......
8	709	710	−0.14
9	199	196	+1.53
10	524	529	−0.95

*Computed for recorded curves chosen at random.
**Two hundred forty equally spaced ordinates were averaged for each.

Acknowledgment

The author wishes to acknowledge the valuable contributions to this project of a number of the author's colleagues at Nela Park, and those of Prof. E. K. Kraybill, Duke University; Omer D. Whitwell, Case Institute of Technology; and Prof. Wendell E. Miller, University of Illinois.

References

(1) "Coefficients of Utilization," by Ward Harrison and Earl A. Anderson, *Transactions of the Illuminating Engineering Society*, vol. 11, 1920, p. 97.

(2) "Luminaire Utilization as Affected by Candlepower Distribution," by C. E. Weitz and C. L. Amick, *Illuminating Engineering*, vol. 43, 1948, p. 65.

(3) "Light Distributions in Rooms," by Parry Moon and Domina Eberle Spencer, *Journal Franklin Institute*, vol. 242, Aug. 1946, p. 111.

"The Interflectance Method of Predetermining Brightnesses and Brightness Ratios, Report No. 3, Committee on Standards of Quality and Quantity of Illumination," *Illuminating Engineering*, vol. 41, 1946, p. 361.

(4) "Optically Corrected Cells," by G. B. Buck II, GENERAL ELECTRIC REVIEW, vol. 51, October, 1948, p. 38.

(5) "The Development of Prismatic Glass Block and the Daylighting Laboratory," by Dr. R. A. Boyd, Engineering Research Bulletin No. 32, University of Michigan, Ann Arbor, Michigan.

"An Illumination Recorder," by A. H. Taylor and W. G. Pracejus, *Illuminating Engineering*, vol. 46, June, 1951, p. 310.

(6) "New Semi-automatic Distribution Photometer and Simplified Calculation of Light Flux," by G. R. Baumgartner, and discussion by F. H. Wyeth, *Illuminating Engineering*, vol. 45, 1950, p. 253.

NEW INSTRUMENTS FROM THE RESEARCH LABORATORY

C. G. Suit

Three useful contributions of research toward accuracy and safety in various fields of industrial production

By DR. C. GUY SUITS
Vice President and Director of Research
Research Services Division
General Electric Company

IN connection with the various projects in which the Research Laboratory has been engaged over the years, its scientists have developed a substantial number of useful instruments for measurement purposes. Among them three recent developments are of special interest. These are: a new film thickness gage, an integrating pole figure goniometer, and a boron-hydride monitor.

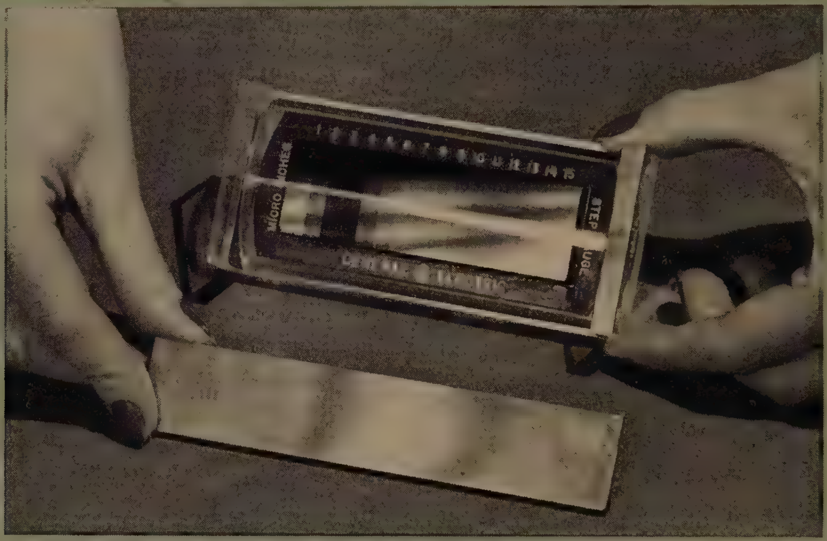


Fig. 1. Step gage (film thickness comparator) in use

STEP GAGE* (Film Thickness Comparator)

The new optical device for measuring the thickness of films, shown in FIG. 1, consists of a film of barium stearate deposited in a series of successive monomolecular layers upon a plate of special glass. Each layer has a thickness of 0.1 microinch, and the successive layers are deposited in such a way as to build a series of steps that differ in thickness by 1 microinch. When the step gage is illuminated by white light, each step reflects a color, which is determined by its thickness. The steps are thus seen as a series of colored stripes on the glass plate. The colors are produced by the interference of light reflected from the front and back surfaces of the film. Since the colors are produced by interference rather than by selective absorption, they are not subject to fading.

The step gage serves as a standard for comparison with other films that reflect interference colors—those that are produced by evaporation, sputtering, plating, etc. The measurement is simple and direct; the color of the unknown is matched with that of one of steps and the thickness read directly from the sca A correction must be made for the refractive index the material.

INTEGRATING POLE FIGURE GONIOMETER

The usability of metal sheet for transformer co can now be quickly evaluated by the use of a ne developed instrument called the Integrating P Figure Goniometer. This device, which is shown FIG. 2, is used to rotate a specimen of the metal sh in an x-ray beam in such a way that the arrangement the small crystallites which make up the metal can determined from measurements of the diffracted bea by means of an x-ray spectrogoniometer. The arran ment of the crystallites in a metal—called the "p ferred orientation," or "texture," of the metal— fluences many of its physical properties. From mea urements of the preferred orientation of the tra former-core material, the efficiency of the transform can be accurately predicted. Such measurements now c be made in approximately one-quarter of the time p viously required. Of even more importance, however, w be the use of this instrument in obtaining fundamen information about crystallite arrangements in meta

---

*More detailed information and a discussion of the pertinent optical p ciples are contained in Research Laboratory Report RL-439, which may obtained upon request, from General Electric Research Laboratory Publ tions, Room 385, The Knolls, Schenectady, N. Y.

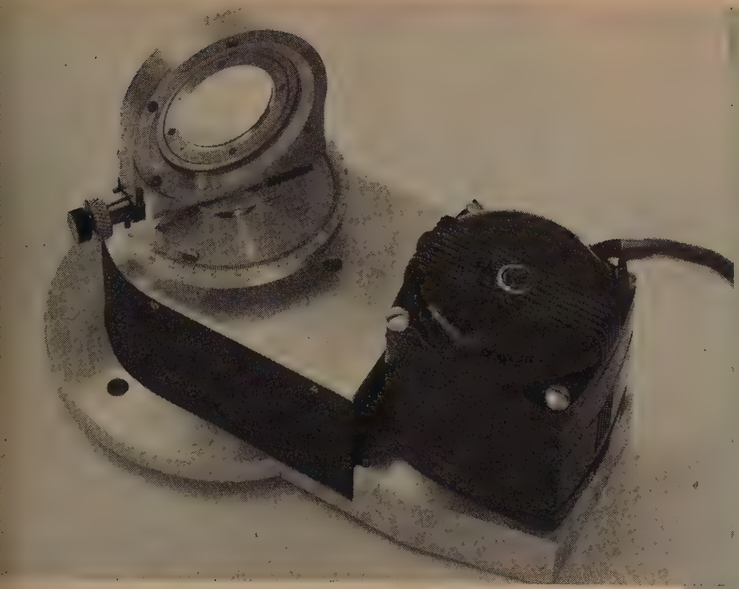


Fig. 2. Integrating pole figure goniometer

BORON-HYDRIDE MONITOR

The high toxicity of boron-hydride vapors made it esirable to develop a sensitive means of detecting the resence of these compounds in air. Making use of the act that boron hydrides will reduce silver salts to etallic silver, a test has been developed which is atisfactory for concentrations as low as one part per illion of boron-hydride vapor in air. The test is made ith a five percent solution of silver nitrate in amyl mine, and the reaction of the boron-hydride vapors ith a wet spot of this solution on filter paper produces a short time a color varying in shade from yellow to rown. The particular solution used gives approxinately the same sensitivity (color intensity) on diorane, pentaborane, and decaborane, and therefore is seful for the monitoring of areas where any one or all hree of these materials may be present.

For use in monitoring laboratory areas in which oron hydrides are being made or used, a simple deice has been constructed in which air samples from ny desired locations are brought to a central point and npinged upon filter papers which are wet with a drop f the solution. The testing equipment is shown in IG. 3. The blowers that suck the air samples from a umber of places in the monitored area are assembled n a panel, shown at the top of the picture. The various amples are then blown over the filter paper, in the mall hood-like device at the bottom of the picture. If s much as one part per million of boron hydride is resent in any of the sample streams, the dark spot evelops within about one minute. Also shown in the hotograph is a small hand-operated device for samling specific areas manually. The aspirator bulb sucks sample of air into the central chamber, which conains the filter paper that has been wet with the soluon.

This spot test, using silver-nitrate solution, has been und effective in plant operations not only for the urpose of detecting the presence of toxic amounts of oron hydrides in the air but also for the purpose of nding leaks in equipment at specific points.

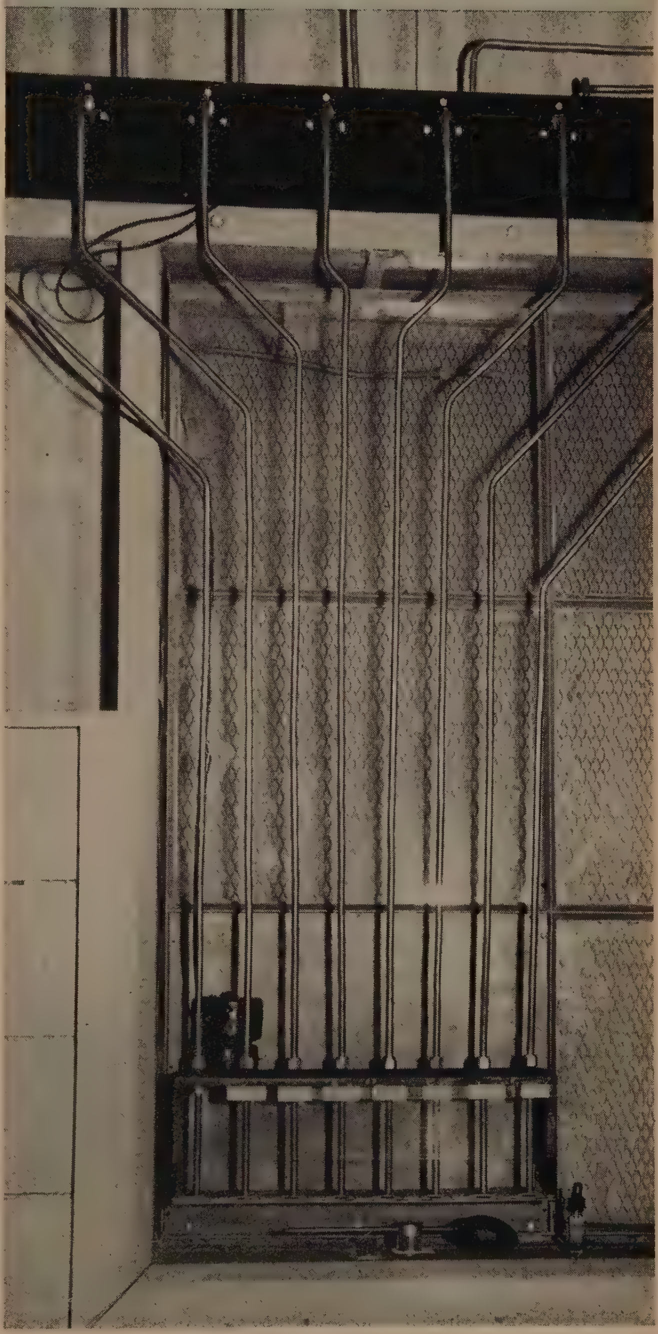
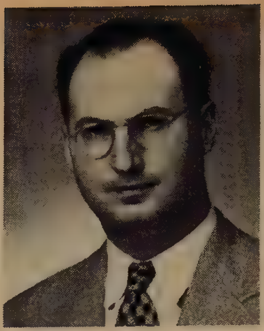


Fig. 3. Boron-hydride monitor for testing laboratory air; in foreground, a hand-operated device for sampling specific areas

DETERMINING WATER CONTENT IN ELECTRICAL INSULATION

A method for quantitatively determining the moisture content in electrical windings to aid in evaluating treatments and procedures

By H. B. BOLSON and R. K. DRAKE
Fort Wayne Works Laboratory
General Electric Company



Harry B Bolson

Robt K. Drak

ONE of the favorite remarks of heat-tormented natives on a sultry summer day is, "'Tain't the heat, it's the humidity." It is well known that the two most common enemies of electrical insulation are heat and moisture. For a specific example of the weather conditions in certain localities, a check was made with the United States Weather Bureau. Their records show that for Fort Wayne and vicinity the average relative humidity for the months of June, July, and August was 58 percent at noon and 83 percent at midnight, with many days attaining a maximum of 98 percent relative humidity. Humidity conditions such as the one mentioned exist in many parts of the United States and in some locations are considerably more severe. The fact that the relative humidity varies so much each day creates extra problems in handling insulation treatments.

This article presents the results of a development carried on in the Fort Wayne Works of the General Electric Company to facilitate the evaluation of drying techniques used in the treatment of electrical windings.

Methods for Determining Moisture Content

The scope of this article is limited to a description of a method for quantitatively determining the moisture content in electrical windings as an aid to future work in evaluating treatments and treating procedures. The investigation posed two problems: one required a physical or chemical method and the other required development of an electrical test method to determine the water content present.

Chemical Method

A variety of methods have been used heretofore to determine moisture content in electrical-insulation systems. Methods depending upon heat and weight become cumbersome when units are over about two hundred grams in weight; moreover, there is no positive assurance that the weight loss should be entirely attributed to moisture. The application of vacuum improves accuracy in that the weight of condensate in the cold trap can be taken. In addition, the actual water can be titrated with Fischer's reagent.(1) A simple reliable method was required to keep abreast of electrical measurements, as well as to correlate the measurement to the water content of the unit.

An apparatus based upon the one described in AST D-95-46 for determination of water in petroleu products and other bituminous materials was use This consists of a Pyrex glass vacuum distilling flas for a pot, a Dean-Stark receiving tube, and an ordinar Liebig condenser (FIG. 1). Clamps were used to assu a tight fit of the cover on the distilling flask. Tolu was used for the boiling medium.

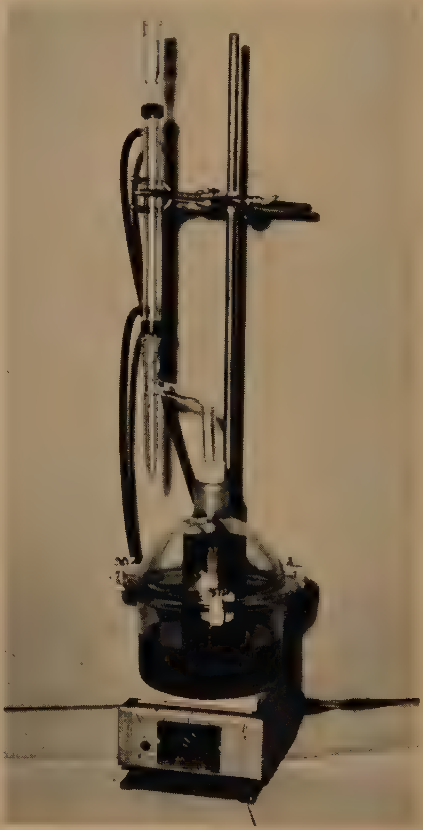


Fig. 1. The apparatus used to chemically determine moisture content in electrical-insulation systems

The method consists of boiling the object under te with a solvent that boils above the boiling point water and which is immiscible with it. As the solve is boiled, the unit under test likewise attains th temperature, causing the water to distill out alo with the distilling solvent. The two are condensed a caught in a graduated receiving tube, where the wat settles to the bottom. The solvent is continuous decanted back into the flask. After a predetermin ne, the amount of water distilled off is read at the eniscus in the graduated receiving tube.

---

(1)A.S.T.M. Designation D890-46T.

The amount of water collected was read in cubic ntimeters after one hour. Although it took four urs to determine the total moisture present, it was und that about 75 percent of the moisture was re-oved in one hour. This percentage was consistent er a weight range of 500 to 125,000 grams. Table I ows this relationship.

TABLE I

MOISTURE EVOLUTION

Weight of Core and Coil Assembly (Grams)	Water Removed in Cubic Centimeters				Water Removed 1st Hr (Percent)
	1 Hr	2 Hr	3 Hr	4 Hr	
500	0.9	1.0	1.2	1.2	75
1500	1.2	1.3	1.5	1.6	75
2500	0.6	0.7	0.8	0.8	75
2500	1.4	1.7	1.8	2.0	70
2500	2.8	3.3	3.5	3.6	78
125,000	16.0	18.6	20.0	20.6	78

To facilitate reading the meniscus between the water yer and toluol and to improve accuracy of measure-ent, the Dean-Stark receiving tube and the Liebig ndenser were coated with Dri-Film*. This coating nproved drainage of the condensate down the sides the condenser for about twenty determinations. A ax-like substance distilled out of the core and coil semblies and deposited upon the sides of the con-nser. Acetone was used to clean and dry the tubes ter each determination.

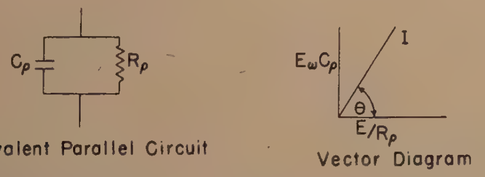


Fig. 2. Diagrams showing the relationship between capacitance, resist-nce, and power factor

ectrical Method

It was expected that varying amounts of moisture core and coil assemblies would cause a change in the sistance of the insulation; thus measurement of power ctor should be a reliable method of determining such anges. An alternating-current bridge of the Schering pe was used for determination of power factor. By ferring to Fig. 2, it can be seen that for a given capaci-nce, as R_P decreases, the angle θ becomes smaller. The gle θ is defined as the dielectric phase angle; and it is e angular phase difference between the sinusoidal ltage applied to the dielectric and the resulting current. The power factor is then the cosine of θ. Therefore, as an electrical measurement of relative moisture content in core and coil assemblies, increasing power factor should mean lower equivalent parallel resistance, and thereby greater moisture content.

Experimental Results

For measurements, the high-voltage lead of the bridge was connected to the coil and the ground side of the bridge connected to the core of the unit under test. A voltage of 500 volts was then applied between winding and core and the bridge balanced. It was found that a guard circuit was not necessary for good balance.

The core and coil assemblies tested tended to have a uniform amount of moisture when received. It was therefore necessary to increase the amount of moisture in some units before testing. This was accomplished through the expedient of placing units in humidity cabinets for varying lengths of time. Electrical tests were made after allowing units to stand at room conditions for one hour.

Seventeen special core and coil assemblies were made up for this investigation. Immediately after the power-factor tests, the moisture content was determined by boiling in toluol, as previously described. A plot of moisture content vs. power factor is graphically represented in Fig. 3.

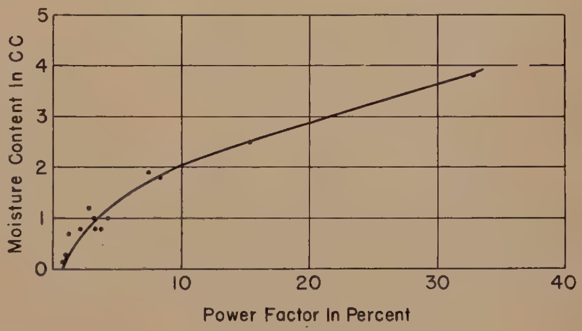


Fig. 3. Curve showing moisture content vs. power factor after tests on core and coil assemblies

If more samples had been taken, a better distribution of points could have been obtained. However, the curve does indicate that there is a considerable change in power factor with increasing amount of moisture. It should also be noted that total moisture content is not the only variable in core and coil assemblies. There is no positive assurance that the moisture in any given unit is uniformly dispersed. Moreover, the capacitance between core and coil will vary as much as 10 percent between units having the same moisture content.

Further tests were made to determine if the same correlation could be obtained after the core and coil assembly had been placed in a case and completely covered with an insulating compound. Before final treatment, the core and coil assemblies were exposed to humidity conditions. Power-factor measurements were made between windings and case and the amount of moisture determined in the core and coil assembly.

Reg. trademark of G.E. Co.

FIG. 4 shows this correlation. Here again, the scattering of points is probably due to the variables previously described.

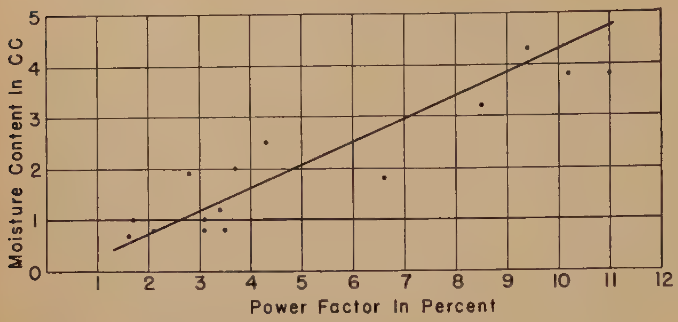


Fig. 4. Curve showing moisture content vs. power factor after tests on core and coil assemblies that were encased

Other Methods

Along with the power-factor measurements, insulation resistance was measured at 500 volts DC, but there was no positive correlation with relative moisture content. Insulation resistance was usually above 20,000 megohms; only in extreme cases of high-moisture content did a change occur.

There was also the thought that leakage-curre measurements might be another means of electrica determining relative moisture content. Such a measu ment can be easily incorporated in a production-l test of insulation in that it could be used in conjuncti with the normal 60-cycle hi-pot tests. By referring ag to FIG. 2, it can easily be shown that in the range 500 to 1000 micromicrofarads of capacitance that large change in equivalent parallel resistance would have much effect on the total impedance at 60 cyc It would be difficult to distinguish between units havi high moisture content and ones which are affected the other variables.

Conclusion

Results of this investigation show that the relat moisture content of core and coil assemblies can determined electrically by power-factor measuremen It is expected that the same correlation could be tained on larger core and coil assemblies.

As a check to determine whether assemblies are pi ing up moisture on the production floor while waiting final assembly, a portable bridge could be used to g advantage.

HIGH LIGHTS AND SIDE LIGHTS

No Focus Coils

Production has begun of television picture tubes designed to operate without focus coils, to save important quantities of copper, nickel, and cobalt—all strategic materials in short supply.

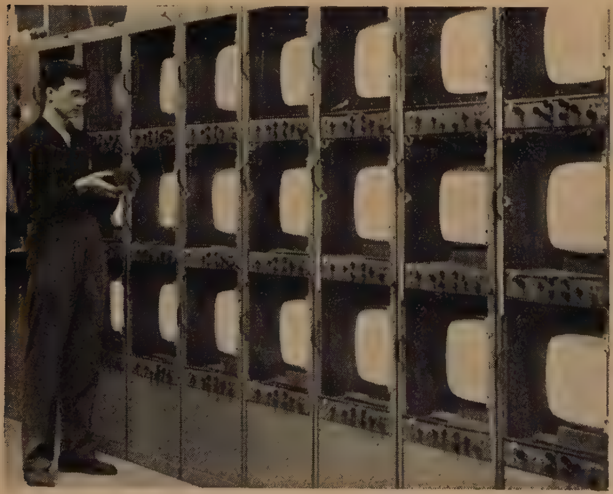
Elimination of the focus coil results from the development of an improved electron gun for zero-voltage electrostatic picture tubes. The new gun design will be incorporated in a series of 17- and 21-in. zero-voltage tubes, first of which to go into production is a 17-in. glass rectangular tube.

In addition to conserving vital materials, elimination of the focus coil will also mean a considerable cost saving for receiver manufacturers.

Although high-voltage electrostatic tubes eliminate use of the focus coil, they require the addition of a focus voltage rectifier and a potentiometer. The zero-voltage tube not only eliminates the focus coil, but does not require addition of any new circuit components.

New design features in the gun structure will insure against arcing within the tube, a condition which has always plagued electrostatic-focus picture tubes because of the high voltage gradient required for focusing action. Conventional magnetic-focus television picture tubes require a cobalt-nickel magnet, a copper coil, or a combination of the two to establish the magnetic field required for focusing.

The zero-voltage electrostatic line will include both glass and metal tubes. Face plates will be spherical as well as cylindrical. The latter type reduces light reflections from illuminating sources in the room.



Life tests are given on 17-in. zero-voltage electrostatic-focus picture tubes.

Slimline Lighting for New Pittsburgh Tunnel

More than three miles of fluoresc lamps, installed in four continuous ba of light, will guide motorists under one the busiest suburbs of Pittsburgh (P

The lighting installation, specially ada ed for underground traffic, will illumin Pittsburgh's new 4226-ft-long Squi Hill tunnel. Designed to meet both pres and future traffic needs, the tunnel will one of the best lighted in the world.

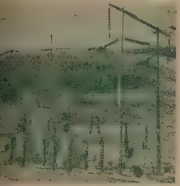
The installation will feature saturat core reactor controls to provide control variation of lighting intensity through the tunnel. Zones of intensive lighting extend 1800 ft into the tunnel from e of the two entering portals to al motorists a gradual eye adjustment fr daylight to tunnel visibility. During ho of darkness, tunnel lights will be of unif intensity. Use of continuous sliml lighting also will eliminate the hyp effect exerted on motorists by the in rupted glow of lamps spaced at reg intervals.

The tunnel's twin tubes, each acc modating two 12-ft traffic lanes, ar part of the Penn-Lincoln Parkway, ultramodern metropolitan roadway ca ing east-west traffic.

Nearly 2000 individual fluoresc lamps, housed in clear Pyrex "pipes," be installed near the top of the sidew Illumination during daylight hours range from four foot-candles in the inte stretches to as high as 20 ft-c at the trance portals.

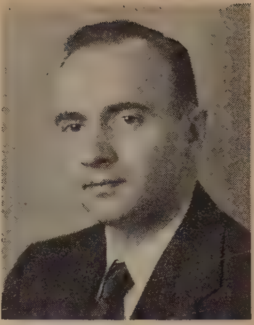
ONTROL AND INSTRUMENTATION EQUIPMENT OR LARGE POWER CIRCUIT-BREAKER TESTING

Unusual requirements imposed by high voltages at extremely high interrupting levels are met in this highly successful application of field testing equipment and control technique



By A. L. STREATER

Switchgear Department Laboratory
General Electric Company



August L. Streater

THE development of power circuit breakers of high interrupting rating to accompany the increasing ncentrations of electric power has established the ed for the field testing of these breakers at the higher terrupting levels. Maximum benefits from these high- vel field tests can be realized only when extensive strumentation is provided to supply complete in- rmation on the interruption performance of the eaker. An integrated set of control and instrumenta- on equipment has been designed and developed for ecific application to breaker field testing and was plied in tests at Grand Coulee Dam Power Plant in ptember 1950, on a 230-kv low-oil-content impulse eaker rated 10,000,000 kva. This equipment proved ghly successful and facilitated the timing of fault plication and breaker operations as well as measure- ents pertinent to breaker performance up to full ting and above full rating to the short-circuit ca- city of the power facilities at Grand Coulee Dam. is circuit breaker test setup is shown in FIG. 1.

The data required for accurate interpretation of eaker field tests involves measurements of arc cur- nt, voltage, and energy; contact travel; the point of ntact separation; pressures developed in the inter- pter; and closing and tripping impulses. The records contact travel and interrupter pressures are often ken at a point of high potential requiring high- ltage isolation of the recording devices. In addition to instrumentation equipment, control equipment is required to provide accurate timing of breaker operations so that test conditions are controlled and reproducible. The equipment assembled to meet these requirements includes both conventional and special items. Special equipment, developed for use in conjunction with conventional recording devices, consists of the following items:

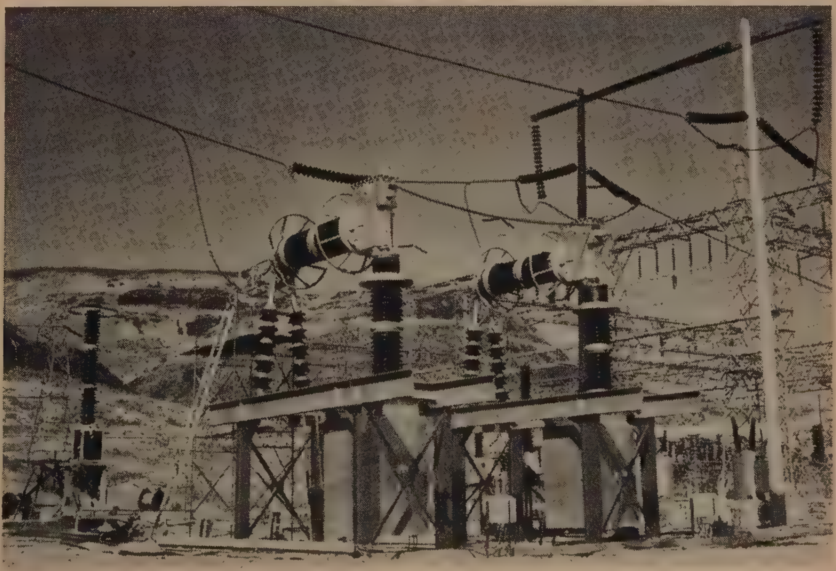
(1). A six-channel, selsyn-thyratron control unit to provide synchronous timing of the fault application and the tripping of the test breaker

(2). A pressure recorder to obtain records of high-speed pressure transients near the high-voltage conductors by frequency-modulated radio transmission of the data from a capacitance-type gage

(3). A contact parting indicator to transmit the instant of contact separation to the oscillograph by frequency-modulated radio.

Control Equipment

The attainment of maximum benefit from breaker field tests requires close control of breaker operations. Accurately timed application of the fault must be provided not only to make tests reproducible but also to obtain maximum offset of the fault current when desired. In order to utilize the maximum current available from the system for interrupting tests it is necessary to part the contacts of the test breaker during the first cycle



. 1. Grand Coulee impulse circuit breaker test ip, showing breaker under test *at left* and breaker d for applying fault, with accurate control of contact ing, *at right*. Frequency-modulated transmitter for sure recorder and for contact parting indicator, for with instrumentation equipment placed in control m and not shown in photograph, are located at left of interrupter unit of breaker under test (*at top of der*)

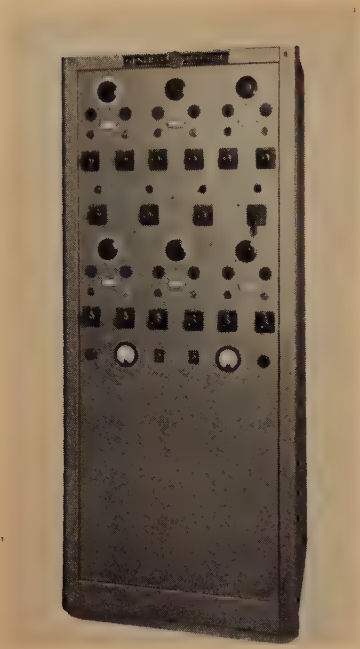


Fig. 2. Synchronous control unit, front view

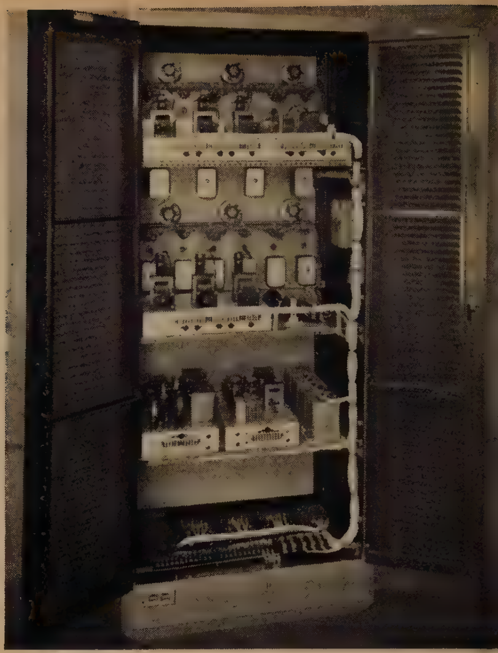


Fig. 3. Synchronous control unit, rear view

of the fully offset current wave. Reclosures must be accurately timed, back-up protective breakers tripped, and recorders set in motion at the proper instant to record the desired phenomena. These functions are provided by the synchronous-control unit shown in Figs. 2 and 3.

The synchronous-control circuit is a six-channel timer that provides 125 volts d-c to closing and tripping coils at predetermined intervals. Each channel can be set to operate at any desired point of any cycle of a reference voltage within the range of 1 to 50 cycles after the oscillograph motors are energized. The controls associated with each channel at the front of the unit are as follows: an Off-On switch for the channel; a switch to close the circuit manually without time delay; two cycle-selector switches, the first indicating the first digit and the second indicating the second digit of the selected cycle; and a phase-shift dial graduated in hundredths of a half-cycle. In addition, two indicator lights are provided with each channel to permit a quick visual check on the circuit before initiating a test. One of the lights indicates continuity of the external trip circuit and the other indicates the continuity of the thyratron filament.

Synchronous timing is accomplished with selsyn phase shifters in conjunction with a high-speed accurately performing multicontact switch driven by a two-pole polarized synchronous motor through a 60-to-1 gear assembly. The switch has two poles with sixty contacts per pole so that a new contact is made each cycle.

An elementary diagram of one channel, together with the circuit that insures but one definite sequence for each initiation of a test, is shown in Fig. 4. With the d-c supply on and the timing motor running, closure of the initiate switch fires the "start" tube when the timing switch crosses Contact 59. Prior to ignition of the "start" tube all channels are idle because the return leads of the peaking transformer secondar are open at relay K_1. Operation of K_1 energizes t oscillograph motors and provides a return lead for t peaking transformers. During the next revolution the timing switch, each channel fires at some point o cycle determined by the phase-shift setting, and t cycle during which it fires is determined by the timin switch contact to which it is connected through the position cycle-selector switches. As the timing swit completes a revolution and crosses Contact 57, t "stop" tube fires, which reopens the return lead of peaking transformers at K_2. Before a test can be peated, the d-c switch must be opened to extingui both the "start" and the "stop" tubes.

The timing switch is of the make-before-break type which a contact is made before the previous contact broken. For this reason alternate contacts on Po 1 and 2 are used.

Two oscillograph amplifiers are included in the co trol unit with the switches, meters, and zero-set co trols on the front panel. The amplifiers are located the lower shelf above the transformer bank (Fig. The amplifier at the left is a carrier-type d-c amplifi having an output of 300 milliamp with a maximu sensitivity of about 1 milliamp per millivolt. A 25- carrier frequency is used in order to provide adequa high-frequency response. The amplifier at the right is differential direct-coupled amplifier with a maximu sensitivity of 24 milliamp per volt and an output ran of plus and minus 90 milliamp. A high input resistan (10 megohms) was provided to make it applicable capacitance-divider applications, although in the Gra Coulee Dam tests it was used with the contact-parti indicator.

Measurements Equipment

Three magnetic oscillographs and one cathode- oscillograph record complete information on brea erformance. A set of contacts in the synchronous ontrol unit energizes the oscillograph motors at the roper time to record the test results. In the Grand oulee Dam tests, the oscillograph motors were energized 20 cycles before the closing voltage was applied the fault-initiating breaker, allowing a constant film eed to be reached by the time the fault was applied.

oltage

Oscillograph records of voltage are taken with the id of capacitance dividers on either side of the breaker ground, and oscillograph amplifiers with a very high nput resistance. Each capacitance divider consists of a .001-μf high-voltage coupling capacitor in series with 3-μf noninductively wound paper capacitor. The mplifiers impose negligible burdens on the dividers that d-c components are accurately preserved. A ifferential amplifier connected to the two dividers roduces galvanometer deflections proportional to the oltage across the breaker. To determine more acurately the recovery voltage rate, the voltage across he breaker is also recorded on 50-ft lengths of 35-mm lm with a high-speed camera and a cathode-ray oscillocope. A close divider balance is obtained with small nica capacitors at the oscilloscope deflection plates.

rc Energy

Arc-energy equipment consists of a watt galvaometer driven by a 2500-to-1 current transformer in the aulted line and a differential amplifier connected to the wo capacitance dividers.

urrent

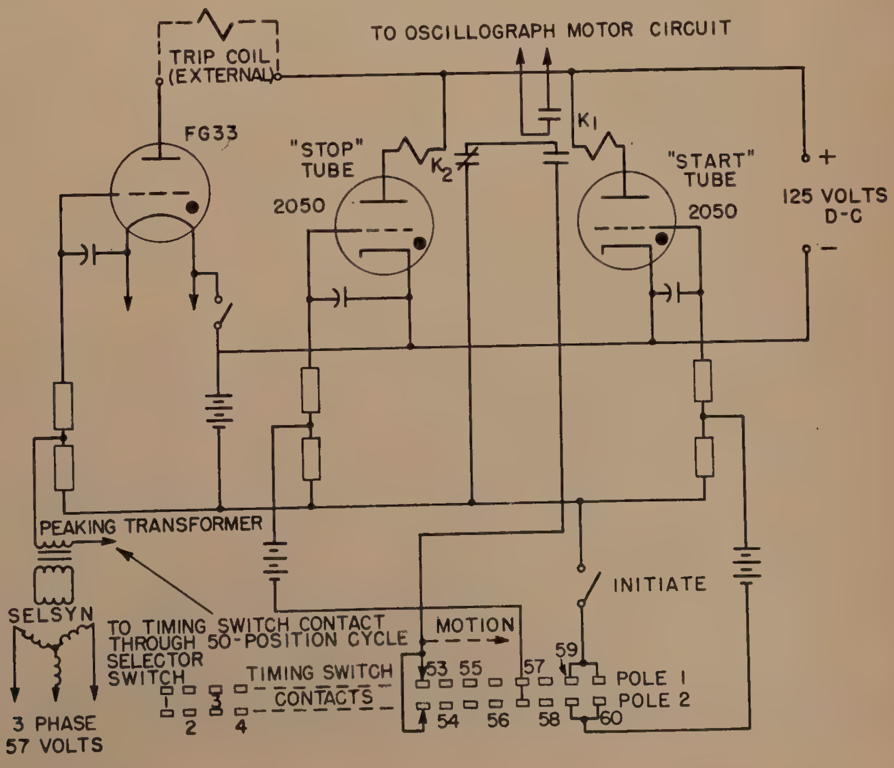
Current records are taken in the conventional maner using a bushing-type current transformer. When ecorded on all three magnetic oscillographs, the current record also serves as a time correlation among the three films used per test.

Travel

Measurements of contact travel at no-load and with solidly grounded faults are provided by a 2000-cycle inductive bridge-type travel recorder, in which the rectified galvanometer current is proportional to the displacement of brass-and-iron cylindrical plungers. To readily determine arcing time, the oscillograph zero-line should be set at the deflection representing the point of the stroke at which the breaker contacts part. Isolation of the oscillograph leads is provided by mechanically coupling the recorder to the contacts with a long insulating rod.

On line-dropping and arcing-ground tests, full line voltage isolation is required and the travel recorder is replaced by a contact parting indicator which transmits the point of parting by frequency-modulated radio. Accurate indication of the instant of contact parting is all that is required; and, because no calibrated magnitudes are involved, very simple apparatus fulfills the requirements. The equipment consists of a battery-operated frequency-modulated transmitter, a frequency-modulation receiver, and an auxiliary set of contacts actuated by the breaker operating rod. The transmitter and auxiliary contacts are mounted on the breaker and float at line-to-ground voltage. The receiver, at ground potential, is located in the control room and connects to the oscillograph galvanometer through a direct-coupled oscillograph amplifier.

The transmitter consists of a single electron-coupled oscillator driving a short vertical antenna. The oscillator is given a step shift in frequency when the breaker-actuated auxiliary contacts close a loop loosely coupled to the oscillator tank coil. The coupled loop is brought



ig. 4. Elementary diagram for one channel of ynchronous control circuit. The timing switch and wo 2050 stages are common to all six channels

out through a coaxial connector to a three-foot length of RG 58U cable which connects directly to the auxiliary contacts actuated by a mechanical coupling to the breaker operating rod.

The receiver employed is a converted frequency-modulation tuner which produces a 4-volt step from the transmitted signal. The high output impedance of the discriminator necessitates the use of an oscillograph amplifier between the receiver and the oscillograph galvanometer. Either of the amplifiers in the synchronous control unit is suitable for this purpose.

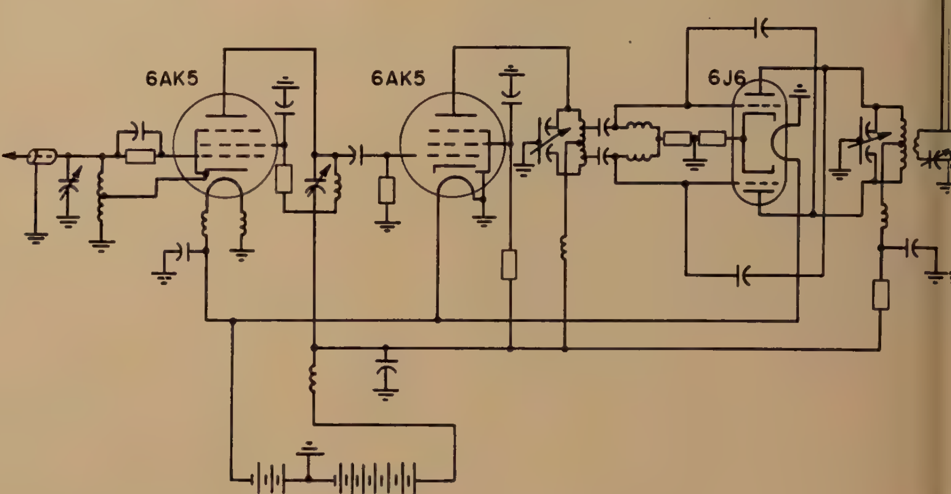


Fig. 5. Circuit diagram for transmitter of frequency-modulation pressure recorder

Pressure

Records of oil pressures developed during an interruption often impose the problem of high-voltage isolation between the pickup device and the recording oscillograph. To record these transient pressures, a frequency-modulation pressure recorder was developed to transfer the data from the breaker to the control room by frequency-modulated radio. The equipment consists of a capacitance-type gage head and battery-operated frequency-modulated transmitter, both located on the breaker and floating at line voltage, and a frequency-modulation receiver in the control room at ground potential. The capacitance gage is connected across the oscillator tank circuit and varies its frequency in accordance with pressure variations on the diaphragm. Although developed primarily to provide high-voltage isolation, the frequency-modulation pressure recorder exhibits other very desirable features as well. Perhaps the most important single feature is its high sensitivity which permits the use of diaphragms with lowest resonant frequencies measured in tens of kilocycles. The high sensitivity is due, in part, to the use of a high carrier frequency as shown by the following equation relating frequency deviation to capacitance change.

$$\Delta f=\frac{-f\Delta C}{2} \qquad (1)$$

Use of a superheterodyne receiver amplifies the percent change in frequency at the discriminator by the ratio of the carrier frequency to the intermediate frequenc This ratio was approximately nine in the record developed. Other factors affecting sensitivity with given diaphragm are the spacing between the plat of the gage capacitor, and the ratio of gage capacitanc to total oscillator tank capacitance. For a gage consistin of a fixed plate, air dielectric, and a circular diaphrag clamped about its edges, the sensitivity is given by th following equation:

$$\frac{\Delta C}{P}=\frac{0.0442\, r^6}{d^2}\left[\frac{1-\nu^2}{Et^3}\right]+\frac{0.00497\, r^{10}}{d^3}\left[\frac{1-\nu^2}{Et^3}\right]^2 P \quad (2$$

in which the following nomenclature applies:

ΔC = capacitance change ($\mu\mu$f)
P = pressure (psi)
r = diaphram radius (inches)
d = plate spacing (inches)
E = modulus of elasticity of diaphragm materi (psi)
t = diaphragm thickness (inches)
ν = Poisson's ratio for diaphram material

Sensitivity thus increases with pressure but is consta within a few percent if ΔC at maximum pressure small relative to the gage capacitance. The percent i crease in $\frac{\Delta C}{P}$ at maximum pressure is approximate twice the percent change in gage capacitance at max mum pressure. The deviation from linearity was negl gible in the recorder developed, the first term alo defining the sensitivity.

For a given diaphragm resonant frequency, the sens tivity is independent of diaphragm radius and thickne but inversely proportional to the square of the pla spacing. The gage was therefore designed on the bas of plate spacing to give the desired sensitivity. If t sensitivity is made too high, difficulty is encounter in reaching the higher pressure ranges with diaphrag of reasonable thickness. The sensitivity equation w derived from the equation for bending deflections, a as the thickness becomes an appreciable fraction aphragm radius, deflections due to shear stresses beome appreciable, making the sensitivity even greater ian that indicated by Equation (2). In the final gage esign, a plate spacing of 0.012 in. was used, providing ily a fraction of the potential sensitivity inherent in iis type of pressure recorder. The fixed plate, moulded a polystyrene base, is 0.75 in. in diameter and reılts in a gage capacitance of 8 $\mu\mu$f. Replaceable diahragms are clamped at a 0.5-in. radius with an "O" ng used to exclude oil from the space between the lates. The diaphragm used in the Grand Coulee Dam ests was 0.150 in. thick and had a pressure range of 500 psi with the circuit employed.

The schematic diagram of the transmitter is shown FIG. 5 and consists of an electron-coupled oscillator-oubler, driver, and power amplifier. The transmitter iassis is suspended in the case by eight springs, and ie case in turn is mounted on the breaker through ord shock mounts in order to reduce to a negligible alue spurious signals as a result of mechanical shock uring a breaker operation. The gage is connected to ie transmitter by a length of RG 11U cable. The ength of cable employed is important because it must resent to the oscillator tank circuit a capacitance that not too large. As used in the Grand Coulee Dam tests iis cable was only about 15 electrical degrees in length t the oscillator frequency. It has since been lengthened several feet in order to more easily adapt it to other reakers. This was accomplished without increase in apacitance by making the cable slightly longer than a alf-wave length at the oscillator frequency. The cable ith gage connected presents an effective capacitance of bout 25 $\mu\mu$f to the oscillator tank circuit and represents bout one half of the total tank capacity. A ceramic immer capacitor is employed for tuning.

The receiver employed is a superheterodyne with wo limiter stages. Direct coupling between the disiminator and the oscillograph amplifier permits the alibration of the recorder on static pressures. The eceiver output voltage is independent of signal strength r input signals above 100 microvolts, so that caliration of the recorder is unaffected by variations in gnal strength above this level. The discriminator utput is essentially linear over an output range of six olts when working into a resistive load of 500,000 ohms.

ield Performance

The first application of this control and instrumenation equipment for power circuit breaker testing was ie 230 kv field tests at Grand Coulee Dam Plant in eptember, 1950. These tests were all single-phase ests on the 230-kv system and included both line-ropping and fault-interruption tests. Line-dropping ests consisted of interrupting the charging current of 00-, 200-, and 300-mile lines. Synchronous trip of the st breaker was used to control and vary, in 45-egree steps, the point on the current wave at which ontacts parted.

The fault tests included open-close tests, close-open sts, and reclosing tests. The final tests were straight opening tests and were made by pretripping the breaker with solidly grounded faults in an endeavor to obtain the maximum fault power of the system. On the last test an equivalent 3-phase fault of 12,000,000 kva was successfully cleared, setting a new interrupting mark. This high fault-current interruption was obtained by pretripping the test breaker so that the contacts parted during the first cycle of a fully offset fault current. Faults were initiated by a second breaker identical to the one under test. The breaker was very consistent in operating time, provided the compressor which supplied the closing power was allowed to build up rated air pressure before a test was initiated, and this consistency in operating time provided an accurate synchronous application of the fault when the breaker closing coil was energized by the synchronous control unit.

Five of the six available timing channels of the synchronous control unit were used in the Grand Coulee Dam tests. One channel provided closing of the fault-initiating breaker and three channels provided opening, reclosing, and reopening of the test breaker. The fifth channel was used to energize the magnetic clutch of a timing cam that tripped the protective breakers and initiated a set of measurements equipment that was set up and operated by personnel of the Bonneville Power Administration to determine the deionization time of the arcing faults.

Excellent results were obtained from the contact parting indicator. There was no apparent interference from the arc and the instant of contact separation was at all times clearly defined on the oscillogram.

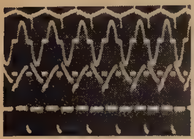
Peak pressures were measured on several tests with a mechanical peak pressure crusher-type gage in which the maximum pressure developed is determined by the set produced in a copper sphere. The correlation between the crusher gage and the frequency-modulation recorder was very good on the lower-current tests. On the higher current tests, the frequency-modulation recorder indicated pressures as much as 30 percent below the values indicated by the crusher gage. The very high rate of rise and short duration of the pressure peaks on the high-current tests indicate the probability that the response of the frequency-modulation recorder was limited by the oscillograph galvanometer.

The success with which the 1950 Grand Coulee Dam field tests were carried out clearly illustrated the important role of an integrated instrumentation. The equipment not only provided extensive data on breaker performance but also provided such close control of breaker operations that tests were easily performed under the most severe operating conditions.

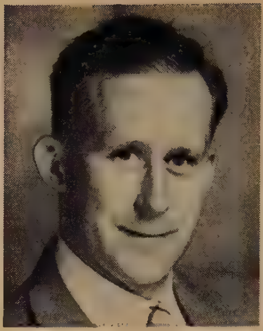
In addition to its availability for future breaker tests, parts of the assembled equipment are continually satisfying numerous measurement and timing applications in the Switchgear Department Laboratory. This is particularly true of the synchronous control unit which has been in use almost constantly since its return from the Grand Coulee Dam tests.

A SIMPLIFIED PORTABLE OSCILLOGRAPH

New features make possible quick on-the-spot records, as well as the usual records of longer-duration phenomena, in a simplified electromagnetic instrument designed for a wide range of practical applications



By J. L. PAINE and D. M. IHLE
Meter and Instrument Department
General Electric Company



J L Paine

Dan M. Ihle

A NEW portable oscillograph has been developed to provide for convenient setup, rapid operation, and simplified maintenance. Other design objectives were to reduce operating expense to the minimum and to eliminate the need for a specially trained operator. Those who use oscillographs at a distance from darkroom facilities find it inconvenient and time-consuming to have conventional records developed. The recent advent of Polaroid Land* film has offered a new means of solving this problem, because it permits the operator to obtain a developed record in one minute and on the spot. The use of this film with the simplified time-sweep mechanism is new in this field of measurement.

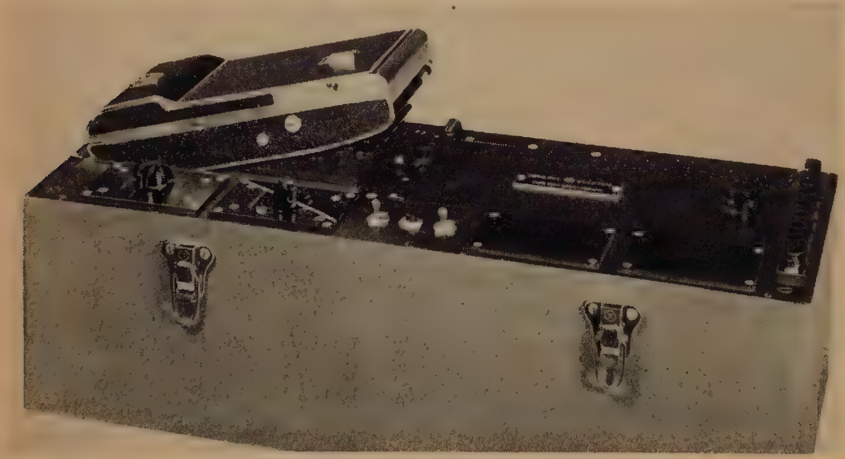


Fig. 1. The oscillograph with Polaroid Land film holder

The oscillograph with the film holder for Polaroid Land film is shown in FIG. 1. For most applications the oscillograph is self-contained. To provide for convenient operation, all controls, rheostat knobs, switches, and binding posts are located on top of the panel. A large removable cover is also provided on the panel to allow easy access to the lamp, fuses, and galvanometers for replacement or adjustment. The oscillograph can be equipped with up to four galvanometer circuits, including all necessary components.

Description

The system elements⁽¹⁾ of the oscillograph are indicated schematically in FIG. 2. The primary detectors are the galvanometers, only one of which is shown in the diagram. The end device includes the recording surfac and the means for producing the time axis on th oscillogram. The functions performed by these element are essential in any conventional magnetic oscillograph In this oscillograph, however, the parts of the en device have been simplified.

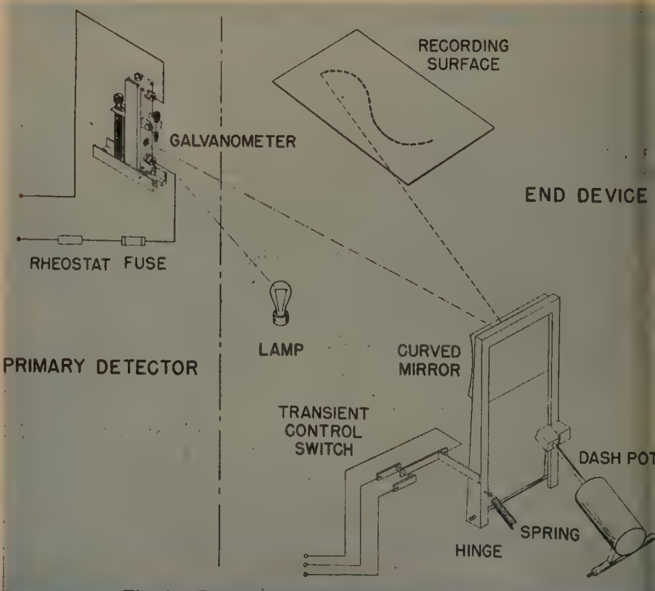


Fig. 2. Functional diagram of the oscillograph

System Components

Optical System

The optical arrangement eliminates lenses, prisms and light cutoffs used in older designs. All the galva iometers are illuminated directly from a lamp having . coiled line filament. The galvanometers reflect an mage of the lamp filament to the curved mirror, where t appears as a vertical line image. The curved mirror ondenses the line image to a small brilliant spot on the ecording surface. This optical system is not only simple o adjust, but also has little chance of getting out of djustment. The lamp is normally operated at underoltage to prolong lamp life, but overvoltage is momentarily applied, automatically, upon depressing the nirror release button. This overvoltage provides righter light for better recording.

---

* Trademark registered, the Polaroid Corp., Cambridge, Mass.
(1) Numbered references are listed at the end of the article.

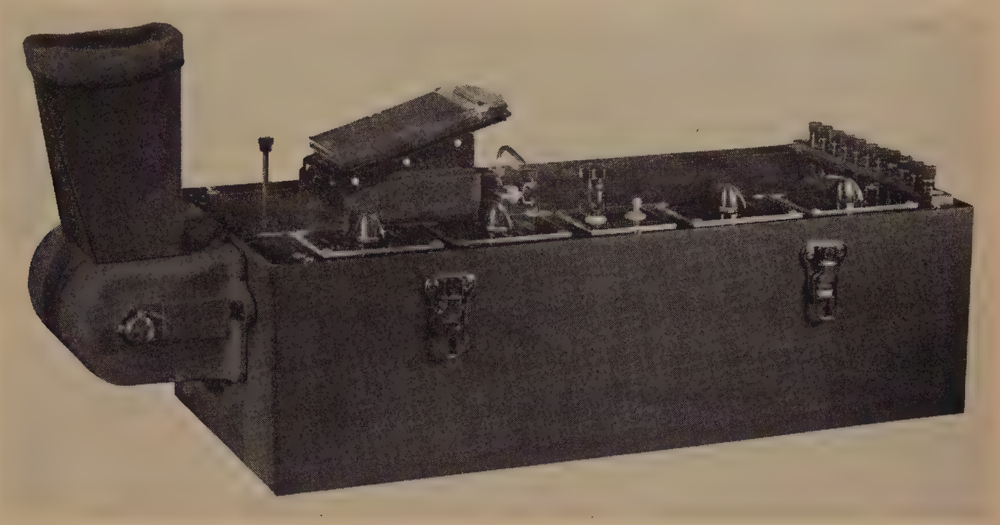


Fig. 3
The oscillograph with viewer attached

To take advantage of the Polaroid Land film and ow-cost film packs, it was necessary to provide for he use of stationary film. This was accomplished by weeping the recording spots along the length of the ilm. The curved mirror shown in Fig. 2 is mounted on . spring-driven hinged bracket. The resulting motion f the curved mirror moves the light spot along the ilm at constant speed. Controls for operating the inged bracket are conveniently located on top of the anel. The total time for the light spot to sweep along he film is designed to be approximately 1/60 sec. Iowever, this time can be increased by connecting an djustable air dashpot, also shown in Fig. 2, to the nirror bracket. When the dashpot is connected, the peed of the time sweep can be varied from 0.1 sec. to .5 sec by turning a needle valve which controls the ate of air escape from the dashpot. This dashpot is ermanently attached in the oscillograph, but can be isconnected easily from the mirror bracket to obtain he fast time sweep. The simplicity of this springoaded bracket and dashpot design results in convenent operation and reduced maintenance not found in lder motor-driven time-sweep designs.

iewing Screen

For convenience in adjusting the position and maxium deflection of galvanometers, a calibrated, transicent screen is located at one end of the oscillograph. his deflection viewing screen is covered by a springoaded shutter which is easily opened to permit viewing of the screen. Wave-form viewing of steady-state conditions is possible with a viewing mechanism which can be assembled to the oscillograph, This mechanism, shown in Fig. 3, contains a revolving four-sided mirror which adds time axis to the line image seen on the deflection viewing screen. This forms an image of the wave form. The mirror is rotated manually by a knurled knob. A flywheel construction and ball bearings are used to sustain rotation over an appreciable period of time to permit effective viewing of wave form.

Film Holders

As mentioned previously, finished oscillograms can be obtained within one minute after a test and without a darkroom by use of the holder for Polaroid Land film, shown in Fig. 1. This holder is the film compartment from a Polaroid Land camera modified with a dark slide and suitable attaching means to fit the oscillograph and uses standard eight-exposure Polaroid Land film.(2) Since the film is daylight loading type, no darkroom is needed. With this film, the oscillograph has a maximum writing speed of approximately 3000 inches per second and will record steady-state or transient phenomena equivalent to a 500-cps frequency at 1.0-in. peak deflection. Since each exposure is 3¼ by 4¼ in., all traces from the four galvanometers are recorded clearly.

Another film holder is made for use with standard plus-X twelve-exposure film packs of 2¼ by 3¼ in. in size. With this film the oscillograph is capable of recording up to 12,000 inches per second, approximately equivalent to a 2000-cycle sine wave of one inch amplitude peak-to-peak. Although standard darkroom developing(3) is required, a transparent oscillogram convenient for multiple reproduction is produced. Certain roll-film adapters and cut-film holders can also be used without modification.

Long records needed for long-time transient and steady-state phenomena can be obtained with the continuous drive record-paper holder shown in Fig. 4. Film or paper records 70 millimeters wide can be made in any length up to 100 ft. Both film and paper records

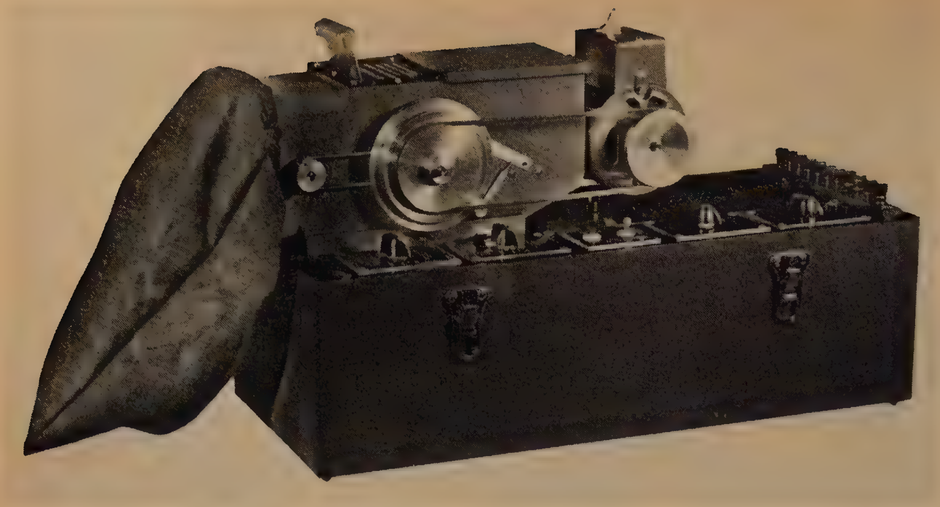


Fig. 4. The oscillograph with continu drive record-paper holder attached

from this holder are developed by normal darkroom procedure. Exposed sections can be cut off and removed from the film holder in a removable bag for developing immediately after each test. The record is driven from the supply to the receiving spool by a sprocket. An external belt-and-pulley drive connected to the sprocket shaft makes possible quick selection of 1, 2.5, or 5 feet per second record speeds. A removable roller carriage is used to reduce loading to the simple operation of feeding the record paper through a slot. An indicator on the side of the case shows the approximate amount of unexposed record remaining on the supply spool. The film holder, as shown in Fig. 4, attaches to the oscillograph in place of the other film holders.

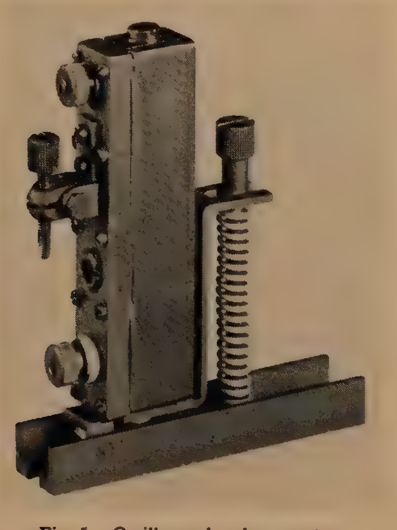


Fig. 5. Oscillograph galvanometer

Galvanometers

Each galvanometer circuit contains a fuse and an adjustable rheostat. This rheostat permits use on circuits up to 200 volts AC or 300 volts DC. The galvanometers used are of the oil-damped bifilar type and, consequently, do not depend on the circuit resistance for their proper damping. This galvanometer is shown in Fig. 5, and is available in four different types for use in the oscillograph with characteristic as shown in Table I.

TABLE I: GALVANOMETER CHARACTERISTICS

Type	DC Deflection Factor (Milliamperes per Millimeter)	Maximum Useable Frequency† (Cycles per Second)	Approximate Resistance (Ohms)
A	0.19	400	8
B	1.7	1300	1.5
C	6.0	3000	0.7
D	19	6000	1.6

† The galvanometers are useable over the frequency range of DC to t tabulated values with amplitude error not exceeding 10 percent.

A transient control switch is incorporated in th oscillograph to permit the recording of short-duratio transient phenomena. This switch is synchronized wit the time-sweep mechanism. It can either open or clos a circuit to initiate a transient, and it will do so durin the first one-fourth to one-third of the record. Test involving transient phenomena are readily made b connecting the binding posts of the switch in serie with the power leads, thus controlling the starting tim of the test.

Applications

Generally, the usefulness of an oscillograph is de termined by its ability to furnish required informatio and its versatility in a large number of tests. On typical application is the obtaining of data necessar to adjust a production spotwelding machine locate at a distance from the darkroom facilities. The con venience of obtaining records on the job is of grea importance, since it minimizes shutdown time of th machine. The final record (Fig. 6) shows the wave for of electrical signals from the ignitron-controlled spot welding machine tested. Trace *A* is the voltage fro a peaking transformer used in the control circuit; is the current through the ignitron tubes; *C* is th current through the weld; and *D* is the voltage acros one ignitron tube. The record shows the duration current flow in individual cycles and provides a co venient means for calibrating the heat-control dia any other important welding criteria could be easured similarly, such as number of cycles per weld, umber of off cycles for intermittent operation, and rrent amplitude.

Another application of this oscillograph is the testing relays and contactors. A typical example of this pe of use is shown in FIG. 7, which is an oscillogram

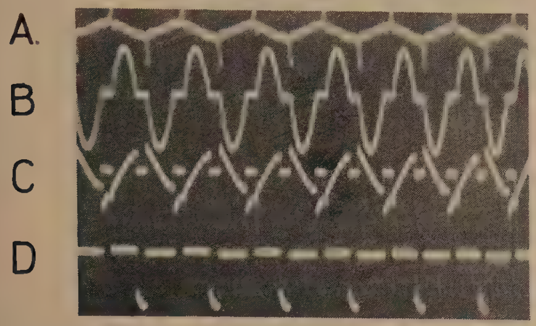


Fig. 6. Oscillogram of spot-welder test, taken on Polaroid Land film

aken while testing a large relay. The problem was to easure the inrush current in the relay field coil, the ne voltage surge, if any, and the length of time reuired for the relay contacts to close after the applicaon of voltage to the coil. Trace *A* is the current through e relay contacts; *B* is the current in the field coil, nd *C* is the voltage trace which serves also as a 60-ycle timing wave. The transient control switch enerized the relay field coil at approximately 1/30 of a econd from the start, thus allowing the transients to e recorded on a short record. A small battery was onnected in series with relay contacts and a galvaometer to show when the contacts closed. Analysis of e oscillogram shows that the closing time of the relay ontacts was 1/30 sec. The relay coil excitation varied om 14.5 amp peak surge current to a steady-state alue of 1.6 amp peak current. This oscillogram shows at the contacts bounced several times after closing.

This oscillograph, with proper equipment, is well uited for many other measurements, both electrical nd mechanical. Dynamic and static strain can be easured by using strain gages and amplifiers with the scillograph. The Type B galvanometer was especially eveloped with suitable resistance, frequency, and deection characteristics for operating from the output General Electric strain-gage amplifiers.

Oscillograms of mechanical quantities related to machinery provide effective means of analysis not possible with other methods of measurement. They are of particular use in trouble-shooting in machines where timing is important. Typical examples of primary detectors for mechanical quantities include torque meters, pressure gages, and custom-built detectors of acceleration, velocity, and position. All of these quantities can be readily recorded with the oscillograph by using suitable primary detectors with amplifiers where necessary.

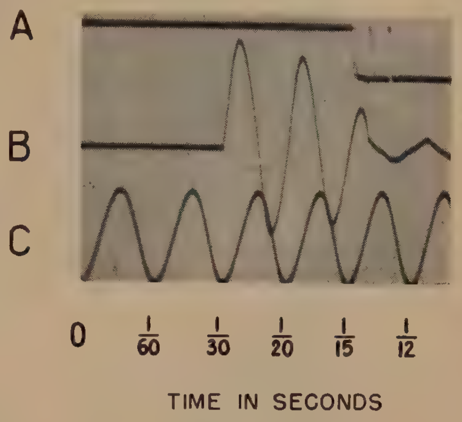


Fig. 7. Oscillogram of relay test

Conclusion

This portable electromagnetic oscillograph has been simplified to such an extent that it can be used by inexperienced personnel. The Polaroid Land film provides a record in one minute, without use of darkroom facilities. Other design features make the oscillograph flexible for numerous applications. The ease and rapidity with which the new oscillograph can be used should encourage more widespread measurement of dynamic quantities, particularly in the solution of mechanical problems.

References

(1)"Functional Analysis of Measurements," by I. F. Kinnard, *Electrical Engineering*, vol. 66, Jan. 1947, pp. 11–15.

(2)"A New One-Step Photographic Process," by Edwin H. Land, *Journal of Optical Society of America*, Feb. 1947, p. 61.

(3)*Kodak Recording Materials*, Eastman Kodak Co., Rochester, N. Y.

Turret for a B-36

In a "dry run," a turret for a B-36 Convair intercontinental bomber is put through its paces. Test engineer operates the control panel as the computer is tested with "dummy" guns before shipment for installation in one of the huge Air Force bombers

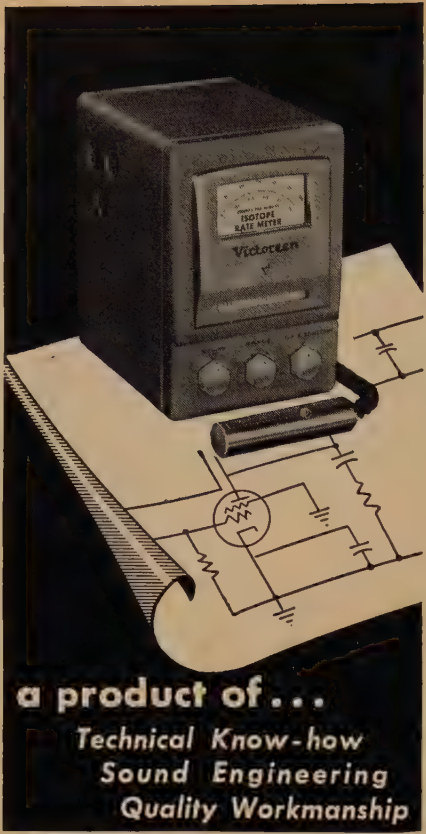
---

CORRECTIONS

In the article "Transmission Losses and Economic Loading of Power Systems," by Dr. L. K. Kirchmayer and G. H. McDaniel, in the October 1951 issue, page 42, the cuts for Fig. 7 and Fig. 8 should be interchanged. The captions are correct.

In the article "Tantalytic Capacitors" by L. W. Foster, the captions for Figs. 20 and 21 should state the rating as 1.0 μf and that the test was at 150 volts.

In addition, the asterisk after the word Tantalytic in the subtitle and the corresponding footnote reference on p. 30 should not have appeared.



a product of . . .
Technical Know-how
Sound Engineering
Quality Workmanship

THE ISOTOPE RATEMETER

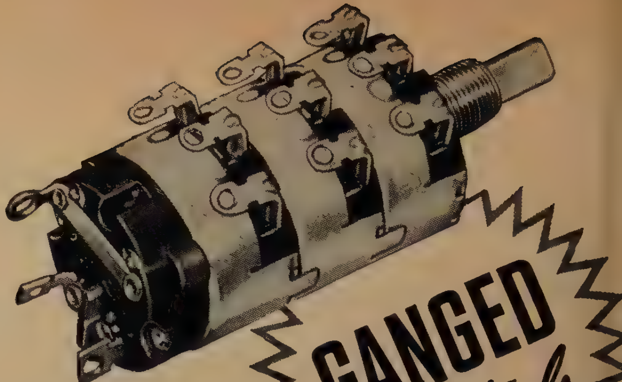
A New
Laboratory Counting Ratemeter

The Model 524—Isotope Ratemeter is a laboratory-quality, counter-type ratemeter for detecting and monitoring alpha, beta, and gamma radiation. It has been designed for the exacting requirements of medical or laboratory personnel for use in chemical or isotope research laboratories. This instrument is applicable to civilian defense and numerous industrial requirements.

A wide selection of counting rates is provided: 0-300, 0-1000, 0-3000, 0-10,000, 0-30,000, and 0-100,000 counts per minute. Aural as well as visual presentation is featured. A three-position meter time-constant switch allows the operator to select the most desirable speed of response. The probe assembly uses standard co-axial base counter tubes and is connected to the case by means of a four-foot flexible cable. The instrument operates from a 115 volt AC supply. The rugged 10 x 7 x 8″ case is finished in gray baked enamel.

For more complete information on the Isotope Ratemeter, write for Bulletin (Form 3002-H).

The Victoreen Instrument Co.
5806 HOUGH AVE. CLEVELAND 3, OHIO



GANGED
Controls

Only 1-1/8″ in dia. Composition-element or wire-wound units mechanically interchangeable

☆

No-wiggle, no-wobble centerless-ground shafts

☆

Two-section tandem available with concentric shafts

☆

High immunity to climatic extremes

★ Nothing more compact or inexpe
sive for simultaneous control of two
three electrical functions! Clarosta
Series 37 (composition-element)
43 (wire-wound) tandems, plus swit
if desired, are made to your exact r
quirements. Rugged. No back las
Choice of resistance, taper, tap.

Engineering Bulletin 112 on request

CLAROSTAT
Controls and Resistors
CLAROSTAT MFG. CO., INC. DOVER, N. H

ASSOCIATED ELECTRICAL INDUSTRIES
• LIMITED •

British Thomson-Houston Co., Ltd.

Edison Swan Electric Co., Ltd.
(Incorporating Harcourts Limited)

Ferguson Pailin Limited

Hotpoint Electric Appliance Co., Ltd.
(Incorporating International Refrigerator Co., Ltd. and Premier Electric Heaters Ltd.)

Metropolitan-Vickers Electrical Co., Ltd.

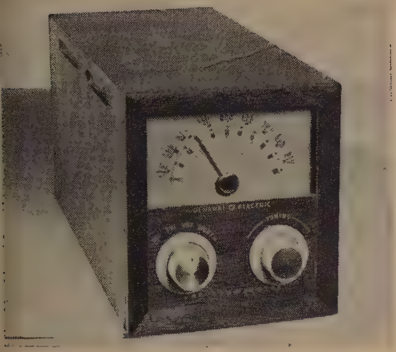
Metropolitan-Vickers-GRS. Ltd.

Newton Victor Ltd.

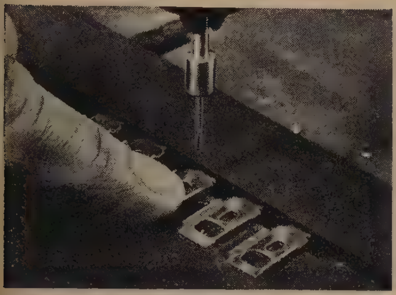
• •

Agents and Licensees of the
GENERAL ELECTRIC Co., U.S.A.
for the United Kingdom.

NEW PRODUCTS: AND WHAT THEIR MAKERS HAVE TO SAY ABOUT THEM



Television Translator



Reamers

Temperature Paints

Temperature Paints

Two products have been added to a line
temperature-indicating materials. One of
ese is high-temperature paints, known as
yromark, some of which withstand tem-
eratures as high as 2500 F. They are
ailable in seven colors. The other product
temperature-indicating paints, called
emp-Alarm, which have the adhesion and
rability of good standard paint but, in
dition, exhibit dramatic color changes at
rious predetermined temperatures.—
empil Corp., 132 West 22nd St., New York
, N. Y.

Spot Welder

A three-phase Modu-Wave machine for
e in the field of electric resistance welding.
ith an electrode force adjustable up to
,000 lb and a rating of 400 kva, this
achine is capable of exceeding the rigid
quirements of the Air Force-Navy Speci-
ations. Up to two thicknesses of ¼-in.
uminum alloys can be spot-welded with
nsistently high-quality results on a heavy
oduction basis. During tests, shear
rength values of ±7 percent were regular-
obtained, and the weld nuggets were free
cracks or porosities. Additional tests
monstrated a 90 percent joint efficiency
lap joints and, under dynamic shock-
ds, the aluminum welds were superior to
mparative riveted and heli-arc welded
ecimens.—*Sciaky Bros., Inc., 4915 W.*
th St., Chicago 38, Ill.

Television Translator

A UHF translator No. 101 designed to operate with all types and makes of television receivers. However, two antennas, one VHF (standard television) and one UHF antenna must be connected to the translator for operating purposes. A traveling dial light is a functional feature. Known as the "dial beam," it automatically spot illuminates the dial when the translator is operated in the "light" position for UHF reception. The light travels with the pointer and spotlights each numeral on the dial face, thus aiding easy tuning. A power outlet socket is provided on the back of the translator. When the television receiver power cord is plugged into this outlet, the left-hand control on the translator switches both instruments on and off. The translator contains the following tubes: 6AF4, oscillator; and 12AT7, IF amplifier. Two selenium rectifiers and one 1N72 high-frequency crystal detector also are used in this translator.—*Electronics Department, General Electric Company, Syracuse, N. Y.*

Reamers

A line of small tools for solving manufacturers' reaming and countersinking problems, so designed that tolerances are held to +0.0002 in., −0.0000 in., or closer. The reamers are carefully ground and honed to give sharp cutting edges and to minimize sticking of the metal to the cutting edge. They are made of carbon steel—heat-treated by special methods that assure a hard surface and a tough, resilient core—or high-speed steel or special alloys. Tool sizes range from 0.005 in. to ¼ in. diameter. Three types of reamers are supplied: flat, half-round, and fluted (spiral or straight). Any of these types are ground to give a taper, two or more steps, or a combination of taper and steps to meet job requirements. —*Woodruff & Stokes Co., Inc., 349 Lincoln St., Hingham, Mass.*

Polarography Instrument

An instrument designed and built to meet the growing need for a precise, reliable, stable, manual polarographic instrument. It is simple and fast to operate and does not sacrifice accuracy and reliability. Features include a 25-turn helical potentiometer accurate to within 0.1 percent, reading to one millivolt with a span voltage of 2.5 volts, which can double this value at a span voltage of 5.0 volts, and a low-resistance galvanometer with sensitivity approximating 0.005 microamps per millimeter.—*Patwin Instruments, Div. of Patent Button Co., Waterbury, Conn.*

Electric Oven

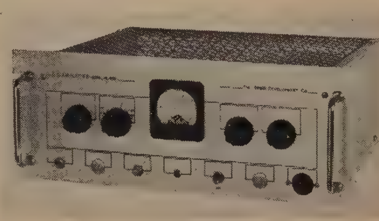
A portable electric oven, Model HT, for processing at high temperatures for stress relief of springs and plated parts. The oven has uniform temperature throughout, the range being from 100 to 800 F. Construction permits the nesting of one oven on top of another. They can be used in groups or banks and can be operated individually, or selected ovens in the group can be cut-out or heated at different temperatures. Constructed of heavy-gage steel with Fiberglas insulation, it will operate from any 110-volt outlet. Thermostat, outside reading thermometer, and pilot light are standard equipment, as are drip pan and lower shelf.—*Grieve-Hendry Co., Inc., 1101 N. Paulina St., Chicago 22, Illinois.*

High-voltage Indicator

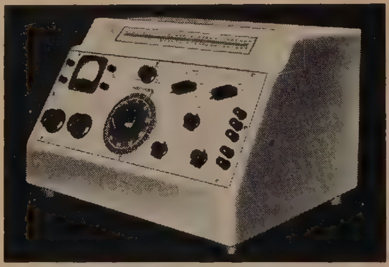
A pocket-size instrument made of safe acrylic resin with well-insulated tip for the service man who wants an immediate check for high-voltage presence. There is no need to disassemble a TV to determine the conditions of the high-voltage circuit, and no VTVM is required; merely probe through back of set into immediate vicinity of high-voltage power supply. The proper functioning of the circuit being tested is immediately shown.—*Javex Co., Garland, Texas.*

Amplifier

A direct-coupled amplifier, Model BL-962, designed for use in standard 19-in. rack and having a 7-in. high front panel. The instrument was designed for use with magnetic direct-writing oscillographs in studies of such static or dynamic conditions as strains, displacements, pressures, light intensities, temperatures, and voltages or currents a-c or d-c. Voltage gain of the instrument, approximately 1000 times, is sufficient to give one millimeter of deflection on the oscillograph chart per millivolt input. Effects of power-line fluctuation are minimized by design features combined with both plate and heater voltage regulation. Zero signal drift amounts to not more than one chart millimeter per hour. When the amplifier is used with the penmotor, the frequency response is essentially linear from d-c to 100 cps.—*Brush Development Co., Instrument Div. 27, 3405 Perkins Ave., Cleveland 14, Ohio.*



Amplifier



Polarography Instrument

Electric Oven

(Continued on following page)

Branching Networks

Branching networks, Series 1130, for use in major broadcasting installations, motion-picture sound studios, and as laboratory standards of fixed attenuation. These multiple input and output networks are used to equalize incoming signal levels—in multichannel mixers and similar broadcast equipment, and to combine two or more incoming lines into a single outgoing line, or to divide one incoming line into two or more outgoing lines. They may be obtained in either balanced "H" or unbalanced "T" circuits. All units are designed for minimum loss. The resistors are of the precision wire-wound type with accuracy of ±2 percent. The maximum level of these pads is +24 VU, and a maximum number of 10 inputs or outputs is available.—*Daven Co., 191 Central Ave., Newark, New Jersey.*

Core-binder Resin

An improved liquid-phenolic-core-binder resin, G-E 12353, especially formulated to meet critical foundry requirements. It permits the molding of stronger sand cores than was possible with former phenolic resins, and it has higher water diluteness and improved handling characteristics. Through its use, baking cycles are reduced to about one-half the time required for conventional vegetable or petroleum-base core oils. The binder also provides less sand "burn in" on the casting, and the excellent collapsibility and easy shakeout lessens the danger of casting breakage. Low gas formation and high gas permeability result in sounder and smoother castings.—*General Electric Co., Chemical Division, Pittsfield, Mass.*

Tape

An extra-thin electrical tape, made with Koroseal material, has these advantages: The adhesive is nontransferring and can be pressed onto a dry surface innumerable times without losing its stickiness; will not transfer the adhesive from the face, lose its tackiness, or ability to adhere; and sticks snugly and securely to itself and insulation around copper wire. The tape has a dielectric strength of 8000 volts; it is waterproof; highly abrasion resistant and flameproof; and resistant to acids, oil alkalies, and corrosive salts. It is easy to use, stretching and conforming readily to irregular surfaces. The tape is packaged in a roll 60 ft long, is ¾ in. wide, and 0.007 in. thick.—*B. F. Goodrich Company, Akron, Ohio.*

Wind-velocity Recorder

A dual-range wind-velocity recorder provides both instantaneous indication and a strip-chart record of wind velocities between 0 and 200 mph. Range 1 utilizes approximately 8 in. of travel for velocities from 0 to 50 mph and is wide open and easily read up through 5 mph. Range 2 utilizes approximately 7 in. of travel for velocities from 5 to 200 mph. Switching from range to range is accomplished either manually or automatically. The instrument is furnished for use with either a directional or a horizontally nondirectional probe. These probes are the thermopile type and have no moving parts. The probes are temperature compensated to eliminate effects of temperature and rate of change of temperature.—*Hastings Instrument Co., Inc., Super Highway and Pine Ave., Hampton 10, Virginia.*

Announcing

ADVANCED SERIES 400 RECORDERS

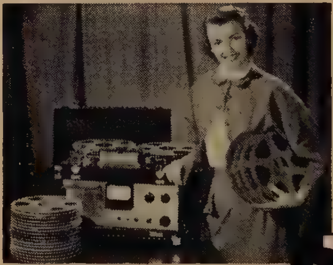
MODEL 400-A
with
Half-Track Head
•
MODEL 401-A
with
Full-Track Head
•
15 & 71/2
Inches Per Sec.

Full **REMOTE CONTROL**

Solenoid operated mechanisms for all mechanical motions.

also *Featuring*

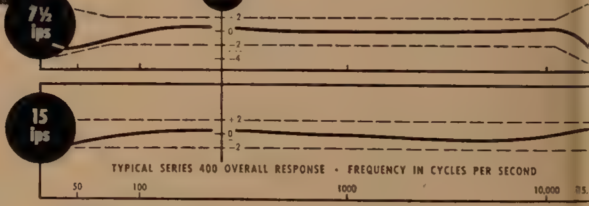
- **UNIFORM RESPONSE** . . . to 15,000 cps at 7½ ins. per sec.
- **LOW NOISE & DISTORTION LEVEL** . . . signal-to-noise ratio over 55 db at either tape speed (as defined by NARTB).
- **PUSH BUTTON OPERATION**
- **LONG LIFE** . . . precision built.
- **LOW MAINTENANCE** . . . even with continuous use.



4 to 1 TAPE SAVING

The valuable tape saving ability of Series 400 Recorders is clearly illustrated above — the young lady holds four reels which contain the identical program formerly requiring the sixteen reels shown on table. No other recorder can give this remarkable tape saving because no other recorder is capable of 15,000 cycle performance at 7½ ins. per sec.; on but half the width of the tape!

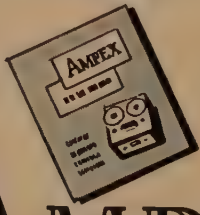
PORTABLE IN SINGLE CASE or for RACK MOUNTING



PERFORMANCE . . . beyond comparison!

Published specifications of Ampex Recorders are conservative these typical check-out graphs on Series 400 show. Ampex chec outs always exceed guaranteed performance but even the guarante performance is sufficient to make Ampex the world's finest recorde

INTERCHANGEABILITY OF TAPES . . . another unrivalled sup riority of Ampex. This means that recordings made on any Amp can be played back on any other Ampex (of like speed) with ide tical high fidelity and timing.



ASK FOR BULLETIN A-211

. . . gives complete description and specifications of the Series 400 Ampex Magnetic Tape Recorders.

AMPEX

AMPEX ELECTRIC CORPORATI
Redwood City, Californ

Distributors in Principal Cities

Magnetic **RECORDERS**

TRADE LITERATURE

PPER CLAD METAL—Designed to furnish ential users of ElectroShield copper clad al with data to determine its applica- y to their needs. It answers such ques- is as: What is it? Where can it be used? at are its characteristics? Four pages. m No. E100.—*American Cladmetals , Carnegie, Pa.*

NAMOMETERS—A booklet on Type TLC -volt d-c dynamometers for direct-con- tion testing of internal combustion ines, motors, pumps, etc. Describes the ures of the equipment, its applications, operation. Supplemented with installa- photographs, a table, and a chart. Four es. GEA-5552.—*General Electric Com- y, Schenectady 5, New York.*

ECTRICAL STEELS—Test data and in- nation are presented on thin electrical ls to aid the selection of such steels for -frequency equipment. Representative results are given in 21 pages of curves. rty-six pages. Titled "Armco Thin ctrical Steels."—*Armco Steel Corp., ddletown, Ohio.*

BRICATION AND FUSION WELDING OF KEL—Two technical booklets, one of ch is on the fabrication and design of kel and high nickel alloy pipe and tubing. s contains tables on mechanical and sical properties, ASME code require- nts, and welding procedures. Twenty- it pages; Technical Bulletin T-17. The er booklet on fusion welding of nickel high nickel alloys includes more than tables of about 50 drawings and photo- phic illustrations covering various forms lectric arc welding, as well as gas weld- . Forty-four pages. Technical Bulletin .—*International Nickel Co., Inc., 67 ll St., New York 5, New York.*

T MOUNTING—A simplified method is lained for selecting the right grade and ght of vibration mounting felt. Also cribes how to install the felt. Twenty es. Titled "How to Reduce Vibration." *merican Felt Co., Glenville, Conn.*

VERNORS—Explains how to get the most of your governor by presenting governor blems and applications. Also describes ration, weight energies, calibrations, ve boxes, shafts, and linkages. Twelve es. Titled "Control."—*Pierce Governor , Inc., Anderson, Indiana.*

ULATION—A group of literature de- bing the Vartex insulating materials uding extruded plastic tubing, varnished s, asbestos, cotton, and silk cloth and e, varnished paper, and resinous sheet- and tape. Four pages each. Product letins Nos. 310, 750, and 750A. Two es each. Product Bulletins Nos. 750B, D, E, and F.—*Insulation Manufacturers p., 565 West Washington Blvd., Chicago llinois.*

SKING PRODUCTS—Describes a masking hod with Quik-Masks—card-mounted -adhesive precut masks and gaskets— ch come in exact sizes and shapes re- ed for masking nameplates, dials, holes, , during spray-painting, cleaning, plat- etc. Four pages. Bulletin No. 160.— *H. Brady Co., Dept. 211, 1602 E. Spring Chippewa Falls, Wisconsin.*

OPTICAL INSTRUMENTS—Three bulletins describing specialized optical instruments. Presented in one is the metallograph for examining, studying, and photographing metal samples and other materials. Four pages. Another shows how accuracy of positioning and linear measurement in machining operations is appreciably reduced by use of the OPL dividing head. Twelve pages; Catalog 10. Optical straightedge principles in measuring and recording variations (1000X magnification) in the flatness of large surfaces, bed plates, veeways, etc. are described in the third. Four pages; Catalog 20.—*F. T. Griswold Manufacturing Co., W. Lancaster Ave., Wayne, Pa.*

SILICONES—The story of silicones—what they are, what they can do, what they have done, and how they can be used to advantage in terms of their four basic properties. Twenty-four pages. CDC-193.—*General Electric Company, Chemical Department, Pittsfield, Mass.*

SWITCHES—A condensed circular for acquainting readers with the entire scope of the Micro switch line of over 5000 switches. The switches are classified, and representative switches in each group are described and illustrated. Four pages. Bulletin 54.—*Micro Switch, Freeport, Illinois.*

TRANSFORMERS—Design and construction features are given on ignition transformers for domestic type automatic oil- and gas-fired heating equipment, as well as benefits of standardization, facts on radio and television interference, and advantages of two-way self-shielding. Eight pages. GEA-5599. —*General Electric Company, Schenectady 5, N. Y.*

TURBINE DRIVES—Turbine Drives for sugar mills is the subject of a bulletin describing the features of the drives, both single and multistage. Turbine application and operation for sugar mills is shown by photographs, sketches, and line drawings. Diagrams explain how adjustable speed governing provides accurate speed control and how the lubrication system operates. Twelve pages. GEA-5692.—*General Electric Company, Schenectady, New York.*

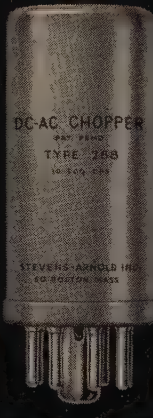
TURBINE OIL MAINTENANCE—A bulletin describing and illustrating dry-type oil maintenance methods for the bearings of modern turbines. Various types of systems are shown with their capacities and dimensions. Factors causing deterioration are explained. Twelve pages. Bulletin 832-P.—*Bowser, Inc., Fort Wayne 2, Indiana.*

TURBINE-TYPE PUMPS—Covers the Class APH-APK line of vertical turbine-type pumps which are applicable to bulk liquid transfer, cooling tower, dewatering, and similar services where suction is taken from an open source. Eight pages. Catalog 7228. —*Ingersoll-Rand Co., 11 Broadway, New York 4, N. Y.*

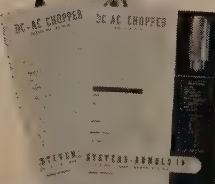
VIBRATING SCREENS—Two types of screens are described: Model UP for the fast accurate dry-screening of light and fine materials, and Model NRM for low-cost high-speed separation of solids from liquids. Text tells how to select proper screens for maximum operating efficiency. Other data include dimension tables, weights, and horsepower requirements. Twenty pages. Book No. 2377.—*Link-Belt Co., 307 N. Michigan Ave., Chicago 1, Illinois.*

DC-AC
CHOPPER

A model for every use.
10 — 500 cycles AC
Meets AN Specifications
also 60 cycles
Single pole and double pole
Make-before-break contacts
Contacts in air or in liquid



These Choppers convert low level DC into pulsating DC or AC so that servo-mechanism error voltages and the output of thermocouples and strain gauges, may be amplified by means of an AC rather than a DC amplifier.
They are hermetically sealed, precision vibrators having special features which contribute to long life and low noise level.



WRITE FOR THESE CATALOGS . . .
#280 10-500 cycles
#246A 60 cycles

STEVENS
ARNOLD
INCORPORATED

22 ELKINS STREET
SOUTH BOSTON 27, MASS.
SA-4

BOOK REVIEWS

JACOBIAN ELLIPTIC FUNCTION TABLES

L. M. Milne-Thomson—Dover Publications, New York. 1950. 123 pp. $2.45.

This book forms a welcome addition to the literature on elliptic functions and will be found useful by anyone who has occasion to use these functions. It contains 39 pages of formulas, expansion for, and various relations between, the classical Jacobian elliptic functions. Tables of the functions sn u, cn u, dn u, to five figures, of Z(u) to seven figures, are given; also, tables of the complete elliptic integrals K, K′, E, E′ to seven places. The notation agrees with the customary notation except for the replacement of k^2 by m.

H. PORITSKY

ELECTRONS AND HOLES IN SEMICONDUCTORS (Bell Laboratories Series)

William Shockley—D. VanNostrand Co., New York. 1950. xxiii+558 pp. $9.75.

Largely as the result of research initiated during the war and continued in several laboratories thereafter, our knowledge of semiconductors has progressed tremendously in the past ten years. The theoretical basis for the understanding of semiconductors rests on quantum mechanics and is familiar to a relatively few specialists. On the other hand, the technical importance of semiconductors is great and continues to grow. There is consequently a need of presentations which minimize the background required for understanding and, at the same time, give clear accounts of the fundamental processes involved and of their interrelation. Dr. Shockley's book helps to fill this need. It deals primarily with electronic processes in the valence semiconductors, silicon, and germanium, to which Dr. Shockley gives the name transistor electronics. This is a field in which the Bell Laboratories group has made major contributions.

The first of the three sections is largely phenomenological, and only the simplest theoretical ideas are used. Characteristics of bulk semiconductors, metal semiconductor contacts, and transistors are treated. The important process of injection of holes and electrons is emphasized. Part II presents the theory in a descriptive manner. Included here are an excellent treatment of the behavior of a hole, a presentation of the theory of conductivity and of the Hall effect, and applications to transistor electronics. Part III gives the fundamental theory on which the earlier parts are based. Introductory treatments of quantum mechanics and statistical mechanics are included.

There are several distinguishing features: Before each topic is taken up, the author in a preliminary treatment takes the reader into his confidence and informs him of the purposes and objects in mind. The result is to help materially in the ease of assimilation. Cross-referencing between different parts of the book is excellent, and the reader can pass easily from the experimental to the descriptive or theoretical treatments of any point. In contrast, the index is less extensive and thorough. Graphs and drawings, some three-dimensional, are numerous and excellent.

The book is recommended without reservation to anyone seriously interested in the electronic properties of semiconductors.

MALCOLM H. HEBB

A NEW THEORY OF GRAVITATION

Jakob Mandelker—Philosophical Library, New York. 1951. 29 pp. $2.75.

Physicists as well as engineers have always been intrigued by the fact that there exist both attraction and repulsion in an electric or magnetic field, while in a gravitational field only attraction is experienced. The author, an assistant professor of mechanics, attempts to fill the gap by introducing the existence of a small radiation force that opposes the gravitational force. He calculates the ratio of the two forces to be the same as that of the mass of electron (radiating matter) to proton (nonradiating matter). The derivations are based upon the hypothesis that the velocity of light is not a constant. As a verification of the theory, the author derives the value of the gravitational constant.

GABRIEL KRON

SUPERFLUIDS—Vol. I: Macroscopic Theory of Superconductivity—Fritz London—John Wiley & Sons, New York. 1950. 161 pp. $5.00.

There are known at present two types of superfluids—fluids which flow without friction. One is exhibited by superconductors, which lose their electrical resistance for temperatures below a few degrees above absolute zero. The other is shown below 2.2 K by liquid helium, a portion of which can flow without friction through very small orifices and cracks. These phenomena result from a momenta-ordering process that is unique in that it represents a quantum mechanism of macroscopic scale.

The outstanding contributor to the theory of these superfluids has been F. London, who with H. London in 1934 presented the electrodynamic theory of superconductivity, and who in 1938 proposed the Bose-Einstein gas model of liquid helium. These major contributions form the core of *Superfluids* of which the present Vol. I deals wholly with superconductivity. The book is written primarily for the specialist, in a very readable style, with excellent figures and general format. It is so comprehensive and well-organized as to constitute a third major contribution to the study of superfluidity.

MILAN D. FISKE

THE ANALYTICAL BALANCE—Its Care and Use

Wm. Marshall MacNevin—Handbook Publishers, Inc., Sandusky. 1951. xiii+60 pp. $1.50.

Selected information needed by the technical worker who uses an analytical balance is presented in this small volume, which will be of value in a variety of laboratories.

There are sections on balance construction, parts, cleaning, use of the balance, testing and adjustment, and analytical weights. Adjustments which require an expert are indicated, and a list of balance repair specialists is supplied. References are given for detailed discussions of some special topics.

The book is a useful aid in testing the quality of a balance on hand but offers little, if any, information of value in selecting a new balance. The procedures described are practical and can be followed, although the text is often difficult to read.

E. W. BALIS

SCIENCE AND THE GOALS OF MAN—A St in Semantic Orientation—Anatol Rapo —Harper & Bros., New York. 1950. x +262 pp. $3.50.

What is "semantic orientation" science? One wades through much ramb talk without an answer. Finally (p. 48) learn that "semantics, a comparatively science, is devoted, among other things the study of the functions and malfunct of language." The "other things" out to be a new system of logic superse Aristotelian logic, a new metaphysics, a new culture. We are told that a word symbol for experience, and as diffe people have different experiences, the s word means different things to them.

Thus, there is no "real" meaning word. To convey our meaning mean convey our experience. This is helped casionally by *synonym, classification, en eration,* or *exhibition;* but the most effec help in enabling the listener to identify meaning is the *operational* definition. In operational sense, language can be like to a road map guiding the listener to meaning; but as in some maps, between original experience and its incorpora into our language, much abstraction distortion takes place.

We are told that Alfred Korzybski constructed the first non-Aristotelian tem of logic and metaphysics, and pres ably also of culture. "The postulates [of new system] are embodied in the princi of *nonidentity, nonallness, multiordina* and *self-reflexiveness.*"

Undeniably there is much to regret both past and present human langu reasoning, and behavior, but mal Aristotle a scapegoat for it and setting Korzybski as a new idol is only anot such exhibit, not a remedy for it. Inven new and high-sounding jargon for sim well-known thoughts is a mark not of dom but of pedantry. Such language particularly apt to conceal an absur that would appear ridiculous if said ordinary words.

To close with a harmless semantici it should be recognized that identity tween this book and "science and the g of man" is purely *linguistic.*

A. BOYAJ

MATHEMATICAL METHODS IN ELECTR ENGINEERING

Myril B. Reed and Georgia B. Ree Harper & Bros., New York. 1951. 338 $5.00.

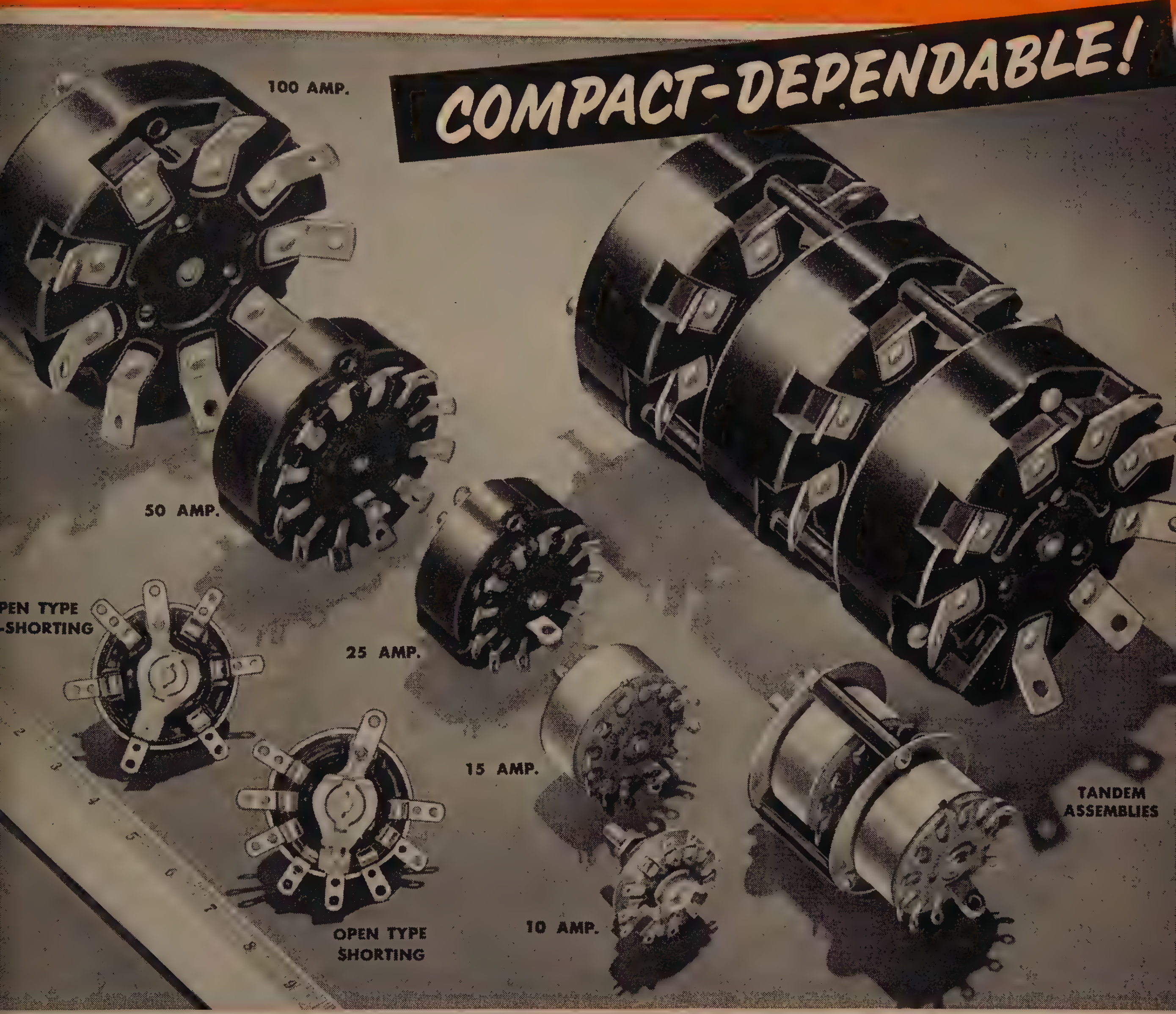
This volume is an attempt to provide the electrical engineer, in a simplified f the mathematical background in hi algebra and subjects beyond calculus w is necessary today. The subjects cov include, among others, matrices and de minants, vector analysis, Fourier se differential equations, and functions complex variable. With such a wide var of topics the authors' treatment is necessa restricted, and covers only the fundamen of each subject. In general, however, presentation is very clear, and is desig to emphasize the aspects useful in elect engineering. This book should prove v able to engineers both as a text and reference work.

R. P. JERR

(Continued on page

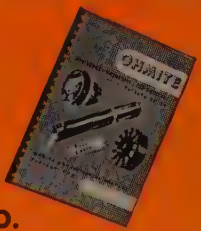
HMITE *Rotary* TAP SWITCHES

HE MOST COMPLETE LINE OF ITS TYPE ON THE MARKET



If you need a compact, high-current, all-ceramic, power-type, rotary tap switch, investigate the Ohmite line. Ohmite tap switches are particularly designed for a-c use. They are available in the single-pole, non-shorting type with up to 12 taps. The self-cleaning, silver-to-silver contacts require no maintenance. The rugged, one-piece ceramic body is unaffected by arcing. Ratings range from 10 to 100 amperes a.c. Two or three of these switches can be grouped in tandem to form multi-pole assemblies. Ohmite tap switches are also available in open-type models for both horting and non-shorting applications.

Write on Company
Letterhead for Catalog
and Engineering Manual
No. 40.



OHMITE MANUFACTURING CO.
4812 Flournoy Street
Chicago 44, Ill.

Be Right with OHMITE

Reg. U. S. Pat. Off.

RHEOSTATS • RESISTORS • TAP SWITCHES

Tempilstik°

A simple method of determining safe operating temperatures for

- **BUS BARS**
- **POWER TUBES**
- **TRANSFORMERS and other electrical equipment.**

also in:

- **MOLDING**
- **CASTING**
- **FORGING**
- **DRAWING**
- **HEAT TREATING**
- **WELDING**
- **FLAME-CUTTING, etc.**

It's this simple. Select the Tempilstik° for the working temperature you want. Mark your workpiece with it. When the Tempilstik° mark melts, the specified temperature has been reached.

$2 each gives up to 2000 readings

Available in these temperatures (°F)

113	263	400	950	1500
125	275	450	1000	1550
138	288	500	1050	1600
150	300	550	1100	1650
163	313	600	1150	1700
175	325	650	1200	1750
188				
200	338	700	1250	1800
213	350	750	1300	1850
225	363	800	1350	1900
238	375	850	1400	1950
250	388	900	1450	2000

Also available in pellet or liquid form

FREE —While we cannot supply free Tempilstiks°, we will be glad to send you sample Pellets or sample Tempilaq° (liquid form) for trial under your actual working conditions. Be sure to state the temperature of interest to you.

Tempil° corp.
132 WEST 22nd STREET
New York 11, N. Y.

BOOK REVIEWS (Continued)

TECHNOLOGICAL APPLICATIONS OF STATISTICS—L. H. C. Tippett—John Wiley and Sons, New York. 1950. 189 pp. $3.50.

This is an excellent book for the person applying statistical methods to technical problems. However, it is neither a basic text nor a comprehensive reference. To understand the author's development and examples, the reader must be acquainted with the mathematics of probability and statistics. One of the most repeated statements in the book is: "Refer to the texts for an explanation of this." The book is, in published form, a series of lectures presented to a heterogeneous audience at M. I. T.

The author covers the two most common types of applications of statistics to engineering work: quality control and the design and analysis of experiments. The text is illustrated with many interesting, practical examples taken from the author's experience.

A large portion of the first half of the book is used to present quality-control charts and their application. The last half presents some of the theory and a number of examples of the analysis of variance (for the determination of the statistical significance of sets of data).

The author presents the material in an extremely interesting manner. However, it should be re-emphasized that a knowledge of the fundamentals of statistics is essential to an understanding of the text.

J. COLEMAN WHITE

RADIATION MONITORING IN ATOMIC DEFENSE

Dwight E. Gray and John H. Martens—D. Van Nostrand Co., New York. 1951. 122 pp. $2.00.

This is a timely book, factual and helpful to any nontechnical novice who plans to assume responsibility in a Civilian Defense radiation monitoring program. The material is well organized and presents in a logical order those subjects of interest and value to the "geigerman." Background information concerning nuclear emanation employed to detect and measure radiations, known aspects of atomic bomb detonation—all these necessary elements in a geigerman's know-how are treated in a nonpedantic manner.

This volume can be recommended as a primer for the instruction of "geigermen" for the Civilian Defense program. However, the servicing of radiation monitoring instruments, which includes repair and calibration, should be left in the hands of the experts and is a subject matter out of scope of this book.

L. J. CHERUBIN

JOHANNES KEPLER: LIFE AND LETTERS

Carola Baumgardt—Philosophical Library, New York. 1951. 209 pp. $3.75.

Kepler, assistant to Tycho Brahe, friend of Galileo, and forerunner of Isaac Newton, won immortal fame by his discovery of the three laws governing the motion of the planets about the sun. "To touch the seven-corded harp of creative wisdom" was his self-appointed task, an object he pursued through thirty years, despite poverty, religious persecution, the suffering of the Thirty Years' War, and a year devoted to the defense of his mother against accusations of witchcraft. The epic story of a scientific genius revealed in this book, and the insight it gives into ways of living in troubled times not unlike our own, make it very well worth reading.

P. L. ALGER

ATOMIC PHYSICS

Wolfgang Finkelnburg—McGraw-Hill B
Co., New York. 1950. 498 pp. $6.50.

This book has a much broader scope t
its title suggests. Half of the pages
devoted to nuclear, molecular, and so
state physics. The descriptive appro
will appeal to teachers and students
sophomore and junior classes but—c
trary to a statement in the preface—
level of this book is quite below the curr
lum of seniors or graduates in this coun

To test the reader's progress and
deepen his understanding a textbook sho
contain exercises. There are none h
even though the book is otherwise
equipped with illustrations and referen
Among the latter, German titles are rat
conspicuous, as *Atomic Physics* is tra
lated from a German manuscript.

There are some confusing stateme
For example, an attempt is made to pres
Heisenberg's uncertainty principle, as
logical consequence of Planck's quant
tion of action." The argument ignores
profound difference between the old the
of quantized orbits and the new quant
mechanics. In the old quantum theo
based on Planck's quantization but bef
Heisenberg, the simultaneous position
momentum of an electron in its orbit co
be determined with unlimited accura
Planck's quantization simply declared t
certain experimental results were exp
able and others were not. Heisenbe
principle, in resolving the wave-part
paradox, constitutes a logical basis for,
not a consequence of, Planck's quantizat
rules.

The section on nuclear reactors conta
the statement, " . . . a mixture of
fissionable isotope 235 with . . . 238
used as reactor material, the percent
of 235 varying with the amount of ene
to be produced." Whatever this may me
it certainly does not help the reader und
stand that criticality and power of a reac
have nothing to do with each other.

Finkelnburg's book presents a pleas
and extensive but somewhat hazy panora
of modern physics. Its most valuable
tures are the chapters on molecular
solid-state physics. These fields have
been covered as thoroughly in the ear
elementary treatments of modern physics

GERHARD DESSA

THE ELEMENTS OF MATHEMATICAL LOG

Paul C. Rosenbloom—Dover Publicati
New York. 1950. 214 pp. $2.95.

Quoting from the preface, "this boo
intended for readers who, while mat
mathematically, have no knowledge
mathematical logic." The author attem
to "introduce the reader to the most
portant approaches to the subject, a
wherever possible within the limitation
space . . . to give at least a few nontri
results illustrating each of the import
methods for attacking logical problems.

The subject of mathematical logic
many years has been considered a bra
of pure mathematics, of interest prima
only from the point of view of pure scie
but by itself rather devoid of applicati
This situation has been changed within
last ten years, since mathematical logic
found interesting and important appl
tions in the design of switching circuits
the study of digital electronic compu
machines, and presumably even in
description of the activity of the brain.
this reason, the present book will be
comed by those who would like to find
what mathematical logic and Boo
algebras are about.

H. PORIT

silicone-treated

Quinterra*

TYPE 3

...a purified ASBESTOS high-temperature sheet insulation with mportant advantages for electrical equipment manufacturers

Silicone-treated Quinterra Type 3 is a high grade, Class H dielectric suitable for both interlayer and wire-wrapped insulation. It has outstanding moisture-resistance, high-temperature stability, and electrical characteristics—plus flexibility and adequate strength. Its unique combination of properties points the way to even greater compactness and even higher overload limits in many types of electrical devices . . . including air-cooled, inert gas and silicone-filled transformers.

High thermal-dielectric characteristics

Quinterra Type 3, like all treated Quinterras, is made from a completely inorganic base sheet of purified asbestos. The base sheet is of closed structure, has no holes, and has an inherent dielectric strength of at least 200 VPM. The silicone-treated base sheet maintains a dielectric strength of at least 350 VPM under continuous exposure to Class H maximum temperature of 180°C. The silicone treatment also provides high moisture resistance so the dielectric strength remains practically constant even under conditions of continuous high humidity.

Excellent physical properties

Quinterra Type 3, is highly uniform in both texture and thickness—an important advantage in product design. Winding dimensions can be predicted accurately and much work can be eliminated in the final assembly. Quinterra is extremely flexible and very resistant to cracking or crazing. Actual use has proved that this insulation has sufficient mechanical strength for economical application in many electrical and electronic units.

Good laminating qualities

Like other Quinterra insulations, the new Type 3 may be successfully combined with other dielectric materials. It may be bonded to other inorganic materials such as mica or glass cloth.

Available forms

Quinterra Type 3 is supplied in sheets, rolls or tapes. Widths—¼″ to 36″—can be cut to your specification. Available in various thicknesses from 3 to 9 mils.

If you have a problem you believe silicone treated Quinterra Type 3 might solve, you are invited to consult our staff engineers. We will gladly supply samples and additional information. Write Johns-Manville, Box 290, New York 16, N. Y.

*Quinterra is Johns-Manville's registered trade mark for its purified asbestos electrical insulation.

Electrical Insulations

LIBRARY NOTES

ON ARTICLES IN OTHER TECHNICAL JOURNALS

ALLOYS

STRUCTURE AND PROPERTIES OF FERRITES, by F. G. Brockman. *Elec. Engng.*, June 1951; v. 70, p. 489.

Discusses the Néel theory, in both the paramagnetic and ferromagnetic regions, and consequences and proof of the Néel theory.

WROUGHT ALUMINUM ALLOYS, by Philip O'Keefe. *Mat. & Methods*, June 1951; v. 33, p. 89.

COMPRESSORS

GUARDED BY POTENTIOMETER WATCHDOGS, by R. N. Grassi and W. H. Wannamaker. *Power*, June 1951; v. 95, p. 90.

Describes the protection of an axial-flow compressor developed to test aircraft gas-turbine components.

SIMPLIFIED DESIGN COMPARISONS OF AXIAL COMPRESSORS, by Frank L. Wattendorf. *Jour. Aero. Sci.*, July 1951; v. 18, p. 447.

ELECTRIC DRIVE

ALTERNATING-CURRENT SUPPLIES FOR A ILIARY PLANT ON BOARD SHIP, by N. Pestereff. *Shipbldr. & Mar. Engine-B* June 1951; v. 58, p. 439.

To show that the use of alternating rent on shipboard results in simplifi tion and reduction in maintenance.

DESIGNING AUTOMATIC OPERATION INT TEXTILE MACHINE, by J. C. Wilson. *E Mfg.*, June 1951; v. 47, p. 112.

Describes electrical controls for hi quality cotton combers.

MOTORS & MOTOR CONTROL, by Victo Kropf. *Chem. Engng.*, July 1951; v. 58 123.

Describes the electric-drive equipm for chemical-process industries.

FLUID FLOW

LAMINAR-TURBULENT TRANSITION IN BOUNDARY LAYER—PART I., by H. Emmons. *Jour. Aero. Sci.*, July 1951; v. p. 490.

Part II will be published in the "Proce ings of the First U.S. National Congr of Theoretical and Applied Mechanics

MECHANISM OF TURBULENT FLUID MOT by Max Munk. *Aero Digest*, June 1951; 62, p. 99.

Describes the transition mechanism fr laminar to turbulent flow.

GAS AND OIL ENGINES

COMPARISON OF SOME TURBOPROP CYC FOR SUBSONIC SPEEDS, by Tibor F. Nag *Soc. Auto. Engrs. Quar. Trans.*, July 19 v. 5, p. 316.

The effects of flight and engine-des conditions on fuel consumption, po per unit engine frontal area, power pound of engine weight, and airpl range are compared for several types turboprop engine.

DIESEL ENGINES FOR TRACTION PURPOS by G. Jendrassik. *Engng.*, June 22, 1951 171, p. 765.

First of a series on diesel engines for traction.

HEATING

HEATING AND COOLING WITH AIR IN RADIANT TILE FLOOR, by L. Bert Nye, *Heat & Vent.*, July 1951; v. 48, p. 72.

Describes a hollow-tile floor heated air in winter and cooled by air in sum that has been used successfully to prov year-round home comfort.

METALS

MACHINE HOT-FORMS TUBING INTO C PLEX PARTS, by John Kolb. *Iron Age*, J 28, 1951; v. 167, p. 78.

How tubing up to 10 in. diam. is precis sized and then hot-formed into comp finished parts.

NORTHROP CHECKS ALL CASTINGS FLUOROSCOPY, by Thomas E. Piper Justin G. Scheeman. *Mach.*, July 1951 57, p. 172.

The principles of a nondestruc method of inspecting vital castings an application are described.

Baking, drying, or heat-conditioning of industrial products in the 150° to 650° F. temperature range, is now simplified by the use of furnace-type Calrod heaters in standard panels for field assembling on pre-fabricated frames. Using both radiation and convection principles for rapid temperature elevation and precise holding requirements, radiant Calrod ovens produce results with shorter heating cycles, lower energy consumption, and little maintenance.

Electric power is delivered throughout the entire heating zone, then converted directly as needed into radiation, convection or conducted heat to balance requirements for pay load, safety ventilation and other processing needs. Balanced thermal design* thus combined with long life dependability, and convertible use construction has made radiant Calrod ovens and booster heaters first choice with many major defense contractors.

Available to engineers on request—design data, cost analysis information, and performance charts. Outline your requirements, including desired heating cycle or end objective, product dimensions, and hourly heating load—we do the rest. Field engineering service also provided for management conferences on defense contract facilities. Write or wire—

CONVECTION * CONDUCTION BTU BALANCED RADIATION

†Reg. U. S. Pat. Off.

ADVANCE HEATING DIVISION
Jensen Specialties, Inc.
9333 Freeland Avenue, Detroit 28, Michigan

TWORKS

NDAMENTAL THEOREM OF ELECTRICAL TWORKS, by J. L. Synge. *Quar. App. th.*, July 1951; v. 9, p. 113.

LUTION OF TRANSIENTS IN ACTIVE FOUR-RMINAL NETWORKS, by Herman Epstein. *nklin Inst. Jour.*, June 1951; v. 251, p. .

How matrix and operational methods together provide a compact, convenient, nd systematic solution of transients.

ASTICS

HESIVES MAY BE THE ANSWER, by rdon P. Hollingsworth. *Modern Plastics*, y 1951; v. 28, p. 79.

The use of adhesives in the design and ssembly of plastics products.

MINATED-MOLDED PLASTICS PRACTICAL R LARGE AND COMPLEX SHAPES, by H. J. rk and J. W. Sawyer. *Mach. Design*, y 1951; v. 23, p. 120.

Manufacture of plastic covers and end bells for marine propulsion gears.

DIO ENGINEERING

RRENT AND CHARGE DISTRIBUTIONS ON TENNAS AND OPEN-WIRE LINES, by D. J. gelakos. *Jour. App. Physics*, July 1951; 22, p. 910.

Describes an experimental investigation of the distributions of current and charge amplitude and phase on cylindrical antennas and on the driving lines.

PLOSION-PROOF LOUDSPEAKER, by Saul J. ite. *Tele-Tech*, May 1951; v. 10, p. 46.

A variable porosity barrier enabling speakers to resist sudden internal or external blasts but permits normal audio transmission.

STEEL

BORON STEELS: A NEW ERA IN ALLOY METALLURGY, by D. I. Brown. *Iron Age*, July 5, 1951; v. 168, p. 79.

Series giving information on boron steels, what they will do, what they won't do, and how they are being applied.

BORON STEELS IN THE PRESENT EMERGENCY, by P. R. Wray. *Steel*, July 2, 1951; v. 129, p. 78.

Initial production heats of five new series of lean-alloy "needled" constructional steels, showing hardenability exceeding laboratory predictions.

WHAT DO YOU KNOW ABOUT STAINLESS?, by Howard E. Boyer. *Steel Processing*, June, 1951; v. 37, p. 287.

For the benefit of engineers who have some metallurgical knowledge, but are interested in engineering materials. Serial.

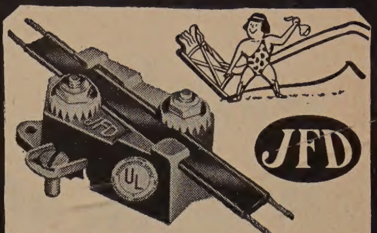
WELDING

EXPLOSION BULGE TEST STUDIES OF THE DEFORMATION OF WELDMENTS, by Carl E. Hartbower and William S. Pellini. *Weld. Jour.*, June 1951; v. 30, p. 307s.

Semiworks-scale testing of full welds in heavy plate under combined stress conditions such as prevail in structures, and the significance of the findings in evaluation of weld performance.

JOBS YOU CAN DO WITH BRONZE ELECTRODES, by F. E. Garriott. *Weld. Engr.*, July 1951; v. 36, p. 20.

How versatile bronze electrodes can be used both to join metals and for overlays. In joining, they are used to weld both like and dissimilar metals and alloys.



PERFORMANCE
Not Size
IS WHAT COUNTS

"LITTLE GIANT"
LIGHTNING
ARRESTER
PROTECTS
Against Lightning Hazards

No. AT 105
For ribbon-type and oval jumbo twin lead.
$1.25 LIST

ONLY JFD Lightning Arresters offer you these exclusive patented features . . .

1. Strain-relief Retaining Lip prevents pulling or straining of lead against contact points.
2. You actually see positive contact made with lead-in wire.
3. No wire stripping or cutting.

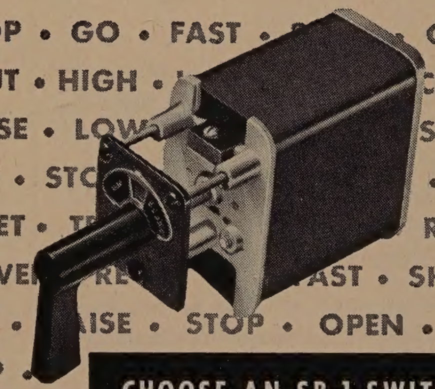
Write for Form No. 84 showing the damage lightning can do to a Television Installation.

JFD MANUFACTURING CO., Inc.
6127 16th AVENUE, BROOKLYN 4, N. Y.
FIRST in Television Antennas and Accessories

JENSEN SPECIALTIES, INC.

NEW ADVERTISER
IN THIS ISSUE ON PAGE 58

SEXTON CAN COMPANY
Incorporated
Everett Massachusetts
Manufacturers of
Ash Barrels
Kitchen Waste Cans
Underground Garbage Receivers
CAPACITOR CASES
both Fabricated and Deep Drawn
FIVE GALLON
Open and Closed Top Shipping Containers
METAL STAMPINGS
SPECIAL SHEET METAL WORK



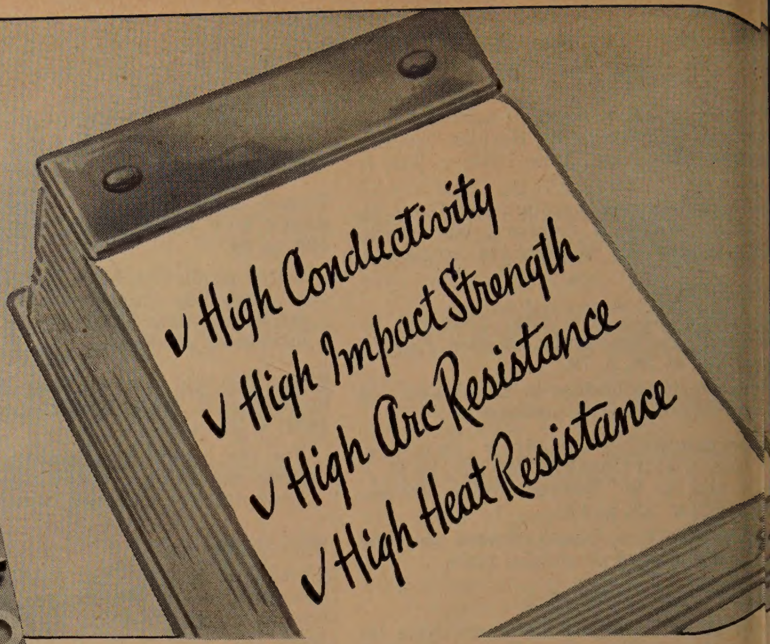
STOP • GO • FAST • OPEN
SHUT • HIGH • CLOSE
RAISE • LOW SLOW
OFF • STO • GO
RESET • RAISE
LOWE AST • SHUT •
OFF • ISE • STOP • OPEN • GO
TRIP •
START •
OPEN •

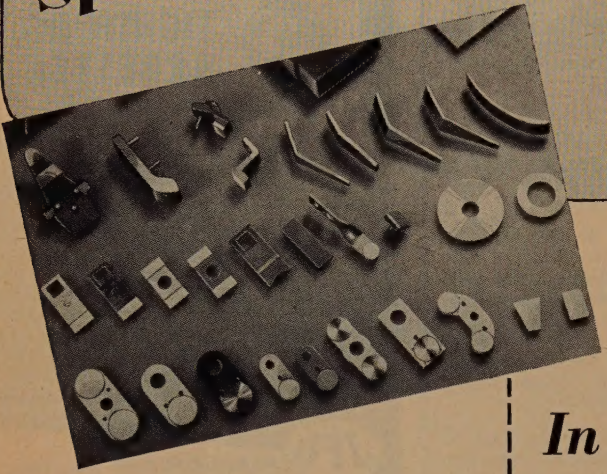
CHOOSE AN SB-1 SWITCH
FOR YOUR CONTROL JOBS

You can use this sturdy, versatile control and transfer switch on practically any circuit for practically any job—over 10,000 circuit-sequence combinations are possible. Rated up to 20 amperes at 600 volts a-c or d-c; and standards are ready on four weeks delivery. Easy to order, too. Mount on panels 1/8 to 2 inches thick. Switch shown is 8 1/4 inches overall, 2 3/4 inches wide, 4 1/4 inches high. See your G-E sales representative and write for bulletin GEA-4746. *Apparatus Department, General Electric Company, Schenectady 5, N. Y.*

GENERAL ELECTRIC
856-21

Result Beyond Specification!





Exclusive Techniques Assure Top Performance In Elkonite* Contact Materia

ELKONITE CONTACTS

Elkonite contacts are made by the only method which permits the combining of the desirable features of basic metals which cannot be alloyed. By this means, the high melting points of tungsten, molybdenum, or their carbides, can be combined with the current-carrying ability of silver or copper.

Elkonite materials are best known for their hardness, resistance to mechanical wear and impact, resistance to erosion by arcing, and resistance to sticking.

Reg. U. S. Pat. Off.

***The ability of a contact material to withstand the erosion of an electric arc.*

The secret of Elkonite superiority is the technique by whic this composite material is made to retain such a high degree c the desirable properties of each of the constituent metal Mallory engineers have so developed this art that no othe contact material has equalled Elkonite in all four features th spell top performance every time . . . conductivity, impa strength, AR** factor, and heat resistance.

Thus, Elkonite . . . the result of precision compounding t take the best advantage of specific properties . . . can delive an extra measure of satisfaction in service.

That's result beyond specification!

Mallory contact know-how is at your disposal. What Mallor has done for others can be done for you.

In Canada, made and sold by Johnson Matthey & Mallory, Ltd., 110 Industry St., Toronto 15, Onta

Electrical Contacts and Contact Assemblies

P. R. MALLORY & CO., Inc.

MALLORY

P. R. MALLORY & CO., Inc., INDIANAPOLIS 6, INDIANA

SERVING INDUSTRY WIT

Electromechanical Products
Resistors *Switche*
TV Tuners *Vibrato*

Electrochemical Products
Capacitors *Rectifier*
Mercury Dry Batteries

Metallurgical Products
Contacts *Special Meta*
Welding Materials